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PLES I GEOTHERMAL DEVELOPMENT PROJECT

APPENDICES

Prepared for:

U.S. Bureau of Land Management
Bishop Resource Area Office

U.S. Forest Service
Inyo National Forest

Great Basin Unified Air
Pollution Control District

May 1989

Prepared by: Environmental Science Associates, Inc.

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FINAL ENVIRONMENTAL IMPACT STATEMENT

AND SUPPLEMENTAL ENVIRONMENTAL IMPACT REPORT

PLES I Geothermal Development

CA-017-P006-60

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Mono County, California

VOLUME II: APPENDICES

Federal Lead Agency: Bishop Resource Area U.S. Bureau of Land Management

State Lead Agency: Great Basin Unified Air Pollution Control District

Cooperating Agency: Inyo National Forest U.S. Forest Service

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May 1989

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PLES I GEOTHERMAL DEVELOPMENT PROJECT
FINAL ENVIRONMENTAL IMPACT STATEMENT AND SUPPLEMENTAL ENVIRONMENTAL IMPACT REPORT

May 1989

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PACIFIC LIGHTING AND ENERGY SYSTEMS UNIT I
GEOTHERMAL DEVELOPMENT PROJECT
EMERGENCY SPILL CONTAINMENT PLAN

This Emergency Spill Containment (ESC) Plan for the Pacific Lighting and Energy Systems Unit I Geothermal Development Project (PLES I) is prepared in conformance with the stipulations of the Bureau of Land Management (BLM) and the Inyo National Forest; the specifications of the California Regional Water Quality Control Board, Lahonton Basin Region (RWQCB); and applicable federal regulations (40 CFR 112) for a Spill Prevention, Control and Countermeasure (SPCC) Plan pursuant to the Clean Water Act, as amended.

I. PURPOSE

The Purpose of this ESC Plan is to: (1) identify potential sources of spills; (2) define measures which have been taken to prevent spills of geothermal fluid, isobutane or any other substance from the project area; (3) describe spill containment systems which have been engineered into the facility to keep spilled substances confined to the site; and (4) outline response actions which would be initiated in the event of a spill.

II. OPERATIONAL SOURCES OF ACCIDENTAL SPILLS

There are principally two phases of operations (short term and long term) associated with the PLES I project with specific spill prevention and containment measures, as appropriate.

(a) Short term operations include well drilling, testing, and servicing operations; and site construction; and

(b) Long term operations consist of commercial power production and maintenance operations.

With the exception of constructing and drilling make-up well sites, as necessary, most significant short term operations will be completed before the power plant begins commercial production operations. Because the source and composition of potentially spilled substances, the maximum credible size of potential spill events, and the spill prevention and containment measures proposed differ for the short term and long term operations; the ESC Plan has been organized by operation to facilitate identifying appropriate spill response procedures.

A. Well Drilling, Testing and Service Operations

Three generic spill events have been identified which could occur during well drilling, testing, and service operations.

1. Drilling Mud Spill:

Drilling muds (a mixture of water, non-toxic chemicals and solid particles used in drilling operations to lubricate and cool the bit in the hole and to carry cuttings out of the hole) will be discharged into a lined on-site mud pit. Accidental discharge of drilling muds are unlikely, but could occur by overflow of the mud pit, mud pit wall seepage or wall failure, or discharge from equipment failure.

2. On-Site Chemical or Fuel Spills:

Small quantities of diesel fuel, mud additives, and workover chemicals may be stored on-site during drilling, testing or workover operations. A potential exists for small on-site spills of these substances.

3. Loss of Control of a Well (Well Blowout):

Although unlikely, a possibility exists for an accidental geothermal fluid spill or discharge due to temporary loss of well control or a well blowout. Geothermal fluid in the Casa Diablo area is essentially hot salty water (about 200 degrees Fahrenheit after being exposed to the atmosphere, and about 1,300 to 1,500 ppm of total dissolved solids) with trace concentrations of heavy metals. Salt water kill fluid could also be added to wells during drilling operations to facilitate well control. Salt water kill fluid is typically a clear salt water solution of up to 14 percent sodium chloride, or in some extreme well control cases, up to 30 percent calcium chloride.

Because of the differences in specific circumstances in which a geothermal spill might occur it is difficult to estimate how long a spill event would continue; however, experience with geothermal fluids in the Casa Diablo area suggest the maximum credible spill rate from an uncontrolled well would be about 500 gallon per minute.

The possibility of well blowout is greatest during drilling operations. As such, a specific Blowout Contingency Plan and Related Field Development Emergency Plans relative to well drilling operations has been prepared for the project (Appendix I).

B. Construction Operations

During site construction the principal sources of potential spills will be small quantities of diesel fuel and lubricants which may be stored on-site to fuel and service construction equipment. Action described hereafter for well drilling, testing, and servicing operations as they relate to small quantity miscellaneous spills are also applicable to actions to be taken for spills during site construction activities.

C. Commercial Production Operations

There are three principal areas from which accidental spills could occur during production operations, including: (a) the production and injection well sites; (b) the production and injection pipelines; and (c) the power plant site itself.

1. Wells and Well Sites:

A very small potential exists for geothermal fluid to be spilled or discharged from any given production or injection well during commercial production operations from channeling of geothermal fluid around the well bore to the surface as a result of improper or inadequate casing cement; near surface fracturing of casing as a result of a major seismic event; or corrosion of surface facilities at the wellhead. Miscellaneous small volumes of paints, solvents or lubricants temporarily stored on-site during well service operations could also be spilled during the life of the project.

2. Production and Injection Pipelines:

Surface pipelines carry hot geothermal fluid from the production wellfield to the power plant and carry warm geothermal fluid from the power plant to the injection wells. A rupture anywhere along the length of the pipeline would cause a spillage of geothermal fluid. The maximum credible spill volume is estimated to be the total flow (about 5,000 gpm) of geothermal fluid for a five-minute period (or a total of about 25,000 gallons). No other substances would be subject to spilling along the pipeline corridors.

3. Power Plant Site:

There are three principal substances which could be spilled on the power plant site. These substances include: (1) isobutane, (2) geothermal fluid, and (3) miscellaneous substances including diesel fuel or small quantities of solvents or lubricants which may be used on site.

Isobutane is the hydrocarbon working fluid used in the power plant heat exchangers. Up to 20,000 gallons of isobutane will be stored on site at any given time, which represents the maximum potential spill volume. Isobutane could be spilled as a result of a system failure or rupture of either the closed system storage vessels (including the accumulator and the storage tank) or the fluid circulating system. Minor isobutane spills also could result during charging of the system or from small leaks. Isobutane is a highly volatile substance which would vaporize shortly after being spilled under most atmospheric conditions. At temperatures below the boiling point of isobutane, about 14 degrees Fahrenheit, isobutane will not vaporize and will remain in liquid form.

Geothermal fluid flowing from the production wellfield to the power plant heat exchangers, or from the heat exchangers to the injection wellfield could be spilled on-site as a result of a leak or rupture.

An underground diesel fuel storage tank is proposed for the power plant site to store fuel for the emergency diesel fire pumps. Miscellaneous small volumes of paints, solvents, or lubricants may be stored on-site at any given time. Further, the on-site electric switchyard will utilize transformers containing a non-PCB oily substance. Small spills from any of these sources could occur during the life of the project.

III. SPILL PREVENTATIVE MEASURES

Several steps will be undertaken to guard against the possibility of a spill. Each of the identified potential spill areas will have safety features to reduce the likelihood of a spill occurring and to prevent a spill from travelling off-site or leaving the project area.

A. Well Drilling, Testing and Service Operations

During well site construction prior to drilling, each well site will be graded to drain to a lined mud pit. The entire well site will be bermed to contain small spills on-site during drilling and testing operations. Sedimentation basins will also be constructed on each well site to contain site runoff from storm events which may occur during drilling operations. Down gradient sides of cut or fill slopes will be lined with filter fences or hay bales to retard soil erosion and sedimentation in the event on-site containment should fail. Erosion control is the subject of a separate specific Drainage and Erosion Control Plan.

During well drilling operations 10,000 gallons of cold water will be stored on-site to be available to kill the well in the event that well control problems should arise. During power plant operations 50,000 gallons of cold water will be stored within the project area and will be available for well control problems after commercial operations begin.

The possibility of geothermal fluid spills or discharges due to loss of well control or blowout is addressed in the Blowout Contingency Plan and Related Field Development Emergency Plans, incorporated into this ESC Plan as Appendix I.

In addition, a project area-wide spill containment facility will be utilized as a backup containment mechanism to prevent spills from leaving the project area. A complete description of the spill containment facility is provided in section IV.

B. Commercial Production Operations

1. Wells and Well Sites

Except for a small wellhead area (about 60' x 130') well sites will be graded after drilling to natural contours. The reduced wellhead area will be bermed to prevent minor spills from leaving the site such as could occur during well servicing operations.

2. Production and Injection Pipelines

Seamless welded pipes will be used along the entire length of production and injection pipeline to minimize the possibility of leaking connections. Isolation valves will be strategically located within the pipelines to prevent a significant backflow of geothermal fluid, should a leak occur. Major pipeline leaks or ruptures would be almost instantaneously detected by in-line sensing equipment as discussed in Section IV.

3. Power Plant Site

The power plant facility will be diked and drained to an on-site catchment basin of approximately 88,000-gallon design capacity. The catchment basin will collect site runoff and would be available for emergency spill containment. This basin is designed to catch any surface runoff of rain water up to the volume from a 20-year one-hour design storm event. Rain water in the catchment basin will be allowed to infiltrate and evaporate.

Under almost all expected atmospheric conditions, isobutane, if spilled, would evaporate before the spill could spread. Any identified potential spill sources in the power plant, such as the isobutane accumulator and switchyard transformers, will be individually curbed to contain spills during commercial production operations. In the unlikely event that spills are not fully contained by the on-site source specific containment facilities, leakage would flow to the on-site catchment basin. In addition, a fail-safe spill containment facility will be constructed down gradient of the power plant site, as discussed in Section IV, and will provide a redundant means for preventing spilled substances from the leaving the project area. A sample of any contained spilled substance will be analyzed and disposed of in a manner approved by the RWQCB.

C. Area-Wide Spill Preventative Measures

In addition to the area specific spill preventative measures described above the following facility-wide operating procedures will be followed.

1. Equipment and Facility Inspection Program

An inspection program will be implemented to prevent and detect system malfunctions and equipment or facility deterioration which, if allowed to continue, could lead to an accidental spill. The inspection program is designed to provide early warning of the potential for such events in order that corrective and preventative actions be taken.

All major equipment and facilities will be identified for routine inspection on an itemized inspection schedule subsequent to facility construction. The schedule will provide a checklist of potential problems associated with the equipment to facilitate inspection. The schedule will also identify the frequency with which the equipment or facilities are to be inspected. A brief, generic, example of the itemized inspection schedule is provided as Table 1. It is anticipated that the schedule will provide the basis for a comprehensive inspection and maintenance program.

2. Personnel Training Program

A personnel training program shall be implemented for both short term and long term operations. Short term operations conducted by contractors, including: well drilling, testing, and servicing; and site construction will require contractors to instruct their employees to comply with applicable portions of this ESC Plan, particularly with respect to emergency response actions to take in event of loss control of wells.

The training program for power plant operators will include instruction on spill prevention, equipment and facility inspection guidelines, and emergency response actions to be taken in the event of a spill. A scheduled training program for all operators and supervisors will be conducted during their first week of job orientation. Training will include a review of equipment which may be used to control or cleanup spilled substances, and the required safety procedures. All potential spill sources, as defined in this ESC Plan, shall be reviewed and appropriate preventative and emergency spill response measures defined.

IV. EMERGENCY SPILL CONTAINMENT SYSTEM

Prior to well drilling or power plant construction, emergency spill containment facilities will be constructed down gradient of all proposed PLES project facilities. The emergency spill containment facilities will take advantage of the natural drainage in the project area and will be available to contain spilled substances from anywhere in the project area.

A. System Design and Normal Operation

The spill containment facilities will be constructed by installing vertical sluice gates down gradient of the project area on extensions of two existing culverts which drain the project area. One culvert crosses beneath State Route 203 and the second culvert crosses beneath Old Highway 395 (aka Hot Springs Road). The vertical sluice gate details are provided on attached Drawing C-0416/0420-E-101, and the location of facilities are identified on the site Drainage Plan (Drawing C-0416-E-104).

The existing culvert pipes under State Route 203 and Hot Springs Road (County Road #346-A) will be extended to approximately 42 feet from the centerline of the existing road where a concrete headwall will be constructed, as shown on the enclosed drawing C-0416/0420-E-101. A vertical lift gate of the culvert size will be installed on the headwall. The vertical lift gate will have an electric operator for automatic operation and a handwheel for manual operation. The valve will be open under normal operating conditions, but closed in the event of a spill from a pipeline or wellsite. The spill would be held in the containment facility, analyzed and disposed of in a manner approved by the RWQCB.

These containment facilities will be constructed before any new construction or well drilling takes place. Each portion of the project will drain to one of the two spill containment areas as shown on the site drainage plan attached (Drawing C-0416-E-104). Therefore, should any discharges or spills occur during drilling, testing or servicing activities, the spill containment facilities will be in place to handle them.

During the short term well drilling, testing, and site construction activities prior to commercial production, the sluice gates would be maintained in a closed position except to permit natural drainage from rain, snow melt, or spring flow from the area. The closed sluice gates would thereby provide secondary emergency spill containment prior to installation of an automatic control system for commercial production operations. Operation of sluice gates would be manual during this preliminary phase of development.

During normal commercial production operations the sluice gates would remain open allowing natural drainage. However, if a major spill should occur the gates would be closed providing secondary containment of any spilled substance in the project area. The gates could be actuated to close manually from the control room, or the gates would automatically close as a result of a system upset during commercial production operations as described below. Valve position will also be displayed in the control room.

B. Automatic Closure Control System

Automatic operation of the containment sluice gates will be triggered by either of two circumstances.

1. Loss of Electrical Power

The pneumatic closure of the sluice gates will be based on a de-energized to trip philosophy, that is should electric power be lost, the valve actuator (utilizing bottled nitrogen) will close the sluice gates. Thus, under circumstances which could result in both a power outage and a spill, such as a major seismic event, the sluice gate would automatically close providing fail-safe spill containment protection. Low nitrogen pressure will be alarmed and displayed in the control room; thereby, assuring continued availability of nitrogen to close the valve.

2. Geothermal Fluid Flow Rate Imbalance

Automatic operation of the sluice gates will be accomplished by measuring geothermal fluid flow from each production well and to each injection well and transmitting those flow rates to an electronic summation device in the control room. The production well flow (supply) will be totalized as will the injection well flow (return). The totalized production and injection flow will be continuously compared electronically. Under normal circumstances the totalized flows should be equal with minor fluctuations. Should there be an order-of-magnitude difference between the production flow and the injection flow (such as would occur if there were a major geothermal fluid leak or pipeline rupture) the sluice gate valve actuators will automatically close, the production pumps and injection pump(s) will stop, and an alarm will sound and be displayed in the control room.

V. SPILL RESPONSE MEASURES

In the event of discharges or spills, the On-Site Supervisor will make an immediate investigation and initiate emergency spill response measures and notifications as appropriate (dependent upon the type and location of discharge or spill). The On-Site Supervisor will then call out equipment, regulate field operations or do other work as applicable for control and cleanup of the discharge or spill. For off-site spills, responsible agencies, as listed in Section VI, will be notified as soon as practical.

The action required to respond to a spill is dependent upon the size of the spill. Small spills (spills of less than 250 gallons) which are easily containable without endangering watershed will be cleaned up immediately under the direction of the On-Site Supervisor. An incident report will be completed by the On-Site Supervisor for subsequent review by plant management to implement measures to prevent similar occurrences.

Large spills (spills of greater than 250 gallons) or spills which cannot be easily contained, or spills which endanger or have entered watershed, will be managed under the discretionary direction of the On-Site Supervisor, using the guidelines in this ESC Plan. The On-Site Supervisor will proceed to take the necessary action to curtail, contain and clean up the spill. If public safety is endangered the On-Site Supervisor shall immediately contact one or more, as appropriate, of the Emergency Response Agencies identified in Section VI. As soon as practical, the On-Site Supervisor will also notify the appropriate Interested Agencies listed in Section VI.

A. Spill Response Measures During Drilling, Testing and Service Operations

If drilling mud or fluids are spilled, an attempt will be made to contain the spill to the well site. If necessary, repairs will be made to the mud pit or on-site sedimentation basins. The liquid fraction of drilling mud or fluids will be removed by vacuum truck to an available tank for subsequent sampling, analysis, and disposal. The solid fraction will be retained on-site, and also sampled and analyzed for characterization prior to disposal in conformance with requirements of the RWQCB.

Spills of geothermal fluid will be contained on-site in mud pits, sedimentation basins, or within the bermed sites. If a geothermal spill threatens to flow off of the well site, the spill containment gates of the emergency spill containment facility (see Section IV) should be manually closed to prevent spilled materials from leaving the project area. Contained geothermal fluids should be cooled and disposed of in a manner acceptable to the RWQCB.

Small petroleum product or chemical spills should be contained on-site with available manpower. Absorbants should be used to contain the spill and contaminated soil should be sampled, analyzed and removed to a disposal site approved by the RWQCB.

All prescribed safety practices should be followed. The members of the drilling, well testing, construction field and operations crews will perform duties assigned specifically for the situation, following applicable rig or construction safety practices and procedures (See also the Blowout Contingency Plan and Related Field Development Emergency Plans provided as Appendix I).

B. Spill Response Measures at the Wells and Pipelines

In the event of a large geothermal spill, such as may occur from a pipeline rupture, all flow from the production wells will be shut off. The gates of the emergency spill containment facilities should automatically close (see Section IV), and confirmation of the gates closing should be indicated in the control room. As soon as practical, plant operators should visually confirm the gates are closed. In the unlikely event the gates did not close automatically, plant operators should close the gates manually, and keep the gates closed until the spill incident is over. The pipeline leak or rupture should be located and repaired as soon as possible. Spilled geothermal fluids stored in any of the containment facilities will be disposed of in manner acceptable to the RWQCB.

C. Spill Response Measures at the Power Plant Site

Geothermal fluid spills occurring within the boundaries of the power plant site will be managed in the same manner as geothermal spills from pipeline ruptures. The power plant site provides the added opportunity to contain the spill at the site because the on-site site catchment basin has greater capacity than the largest credible spill volume. Spill response measures should parallel those earlier discussed in Section V.B.

Spills of isobutane should be contained within the internally bermed areas of the power plant site. Extreme caution and effort should be provided to keep the isobutane away from potential ignition sources. The source of the leak or the cause of the spill should be identified and repaired or remedied as soon as it is safe to do so. As much of the isobutane as possible should be recovered by vacuum truck and absorbants should be used to collect any material which cannot be recovered by vacuum. The isobutane will then be reclaimed or disposed of in a manner approved by the RWQCB.

In the unlikely event that an isobutane spill should escape the internally bermed power plant site areas, the leakage would flow to the on-site catchment basin. The catchment basin contains far in excess of the total volume of isobutane stored on the site at any given time. The contents of the catchment basin would then be recovered or disposed of in the manner described above.

Given the redundant on-site containment and the vaporization characteristics of isobutane, no off-site isobutane spills can credibly be expected to occur. However, the emergency spill containment facilities described in Section IV could be utilized to contain spilled isobutane if some currently unforeseeable spill incident should occur.

VI. NOTIFICATION PROCEDURES

The drilling supervisor and/or the PLES supervisor (On-Site Supervisor) will immediately notify one or more of the local emergency response agencies, as appropriate, if public safety is threatened by a spill. The On-Site Supervisor will, as soon as practical, contact any contractors required to respond to the spill and will notify the PLES Project Manager.

Local Emergency Response Agencies	Emergency Nos.
Mono County Sheriff Department	911
California Highway Patrol	911
Long Valley Fire District	911
Mammoth Lakes Fire Department	911
Ambulance - Paramedics	911

PLES Project Manager
6055 East Washington Boulevard
Commerce, California 90040
(213) 725-1139

In the event of a large spill, the On-Site Supervisor will follow the same notification procedures provided above. In addition, the PLES Project Manager will notify the following agencies as soon as practical and work closely with them in all phases of the curtailment, containment and cleanup operations:

Responsible Regulatory Agencies:

California Regional Water
  Quality Control Board (RWQCB)
Lahonton Region - Victorville Office
15371 Bonanza Road
Victorville, California 92392-2494
(619) 241-6583

Bureau of Land Management
Bishop Resource Area Office
873 N. Main Street, Suite 201
Bishop, California 93514
(619) 872-4881

Inyo National Forest
Forest Supervisor Office
873 N. Main Street
Bishop, CA 93514
(619) 873-5841

Inyo National Forest
Mammoth Ranger District Office
State Route 203
P. O. Box 148
Mammoth Lakes, California 93546
(619) 934-2505

VII. INCIDENT ASSESSMENT AND SITE RECLAMATION

After a spill has occurred, an incident assessment will be undertaken to determine the cause of the spill and to initiate counter measures to guard against any reoccurrence.

Site reclamation shall be undertaken to repair any damage resulting from the spill and to remove and dispose of wastes or contaminated soils in a manner consistent with the requirements of the RWQCB. Berms, basins and other containment facilities or equipment will be repaired, as necessary. The Erosion and Sedimentation Control Plan will be consulted to ensure conformance with that Plan, and the site will be revegetated as necessary.

TABLE 1
EMERGENCY SPILL CONTAINMENT PLAN
EQUIPMENT AND FACILITY INSPECTION SCHEDULE

EQUIPMENT	CHECKLIST	INSPECTION FREQUENCY
Sluice gates	Open or closed	Once a day
Warning signs	Existent Condition	Once a month
First aid kits	Completeness	Once a month or After use
Absorbants	Stock	Semiannually or After use
Berms	How full Structural soundness	Once a month
Monitoring equipment	Run test checks	Once a month
Pipelines	Leaks Corrosion	Once a month
Wellhead equipment	Leaks Corrosion	Once a month
Valves	Packing Wear	Semiannually
Pipe support	Structural soundness	Semiannually
Tanks	Structural soundness	Annually
Heat exchangers	Efficiency check	Semiannually
Oil-lubricated equipment	Lubrication check	Daily

APPENDIX I

PLES I - GEOTHERMAL FIELD WELL BLOWOUT CONTINGENCY PLAN AND RELATED FIELD DEVELOPMENT EMERGENCY PLANS

The purpose of these plans is to provide guidance to field personnel and management in the event of an uncontrolled well flow (i.e., "blowout") or other field related emergency. The plans are intended to be comprehensive in that they describe the nature of various hazards or problems that might encountered and specify appropriate preventive or anticipatory actions and equipment, as well as specific responses, notifications and follow up procedures that are required in the event of such a field emergency. In addition to blowouts, emergencies such as injury, fire, spills and hazardous gas releases are covered.

A. Blowout Contingency Plan (See also the attached Hazardous Gas Contingency Plan and the Blowout Action Plans)

The Blowout Contingency Plan and related Hazardous Gas Contingency Plan and Blowout Action Plans describe actions and equipment aimed first at preventing blowouts and, in the event of uncontrolled well flow, the specific responses required to regain control and minimize hazards and damage.

1. In order to prevent blowouts the following precautions will be observed:

   a. Blowout prevention equipment will be kept in operating condition and tested in compliance with regulations and industry standards.

   b. During drilling operations, a minimum of 10,000 gallons of cool water and 12,000 pounds of barite will be stored at the well site for use in killing the well.

   c. When pulling or running pumps or conducting other well operations for which only clear fluid should be used to kill the well, the following precautions will be observed:

      i. For wells which are known to have a standing water level below ground level, a minimum 10,000 gallon supply of cool water will be available at the well, either through a pipeline from the plant water supply system or from a storage tank at the well site.

      ii. For wells which are known to have a standing water level near ground level or above, the following items will be kept at the well site:

         . a water supply as described above,

- a tank and circulating pump for mixing up to 4,000 gallons of salt water kill fluid, and
- a minimum of 6,000 pounds of sodium chloride salt or 15,000 pounds of calcium chloride salt, depending on the kill fluid density that would be required to kill the well.

d. In the event of an emergency, such as a blowout, immediate efforts will be taken to shut surface valves and blowout preventer(s).

2. If the means to shut-in or control the flow from the well is lost, the Drilling or Workover Supervisor is to:

   a. Initiate appropriate control procedures.

   b. Arrange for any injured person to be transported by the fastest appropriate transportation to the nearest medical facility, as shown above in the Injury Contingency Plan.

   c. Notify the Sheriff if there is a threat to local residents, at:

      Mono County Sheriff's Department
      Mammoth Lakes, CA
      (619) 934-6058 or 911

   d. If fluid flow is of an uncontained nature, immediately dispatch personnel to close the appropriate containment basin gate and attempt containment by constructing sumps and/or dikes as rapidly as possible and as needed.

   e. Secure and maintain control of access roads to the area to eliminate entry of unauthorized personnel.

   f. Contact the Project Manager and advise of the situation.

   g. Follow cleanup and abatement procedures of the Spill or Discharge Contingency Plan - Section D.

   h. Initiate any further or supplemental steps which may be necessary or advisable, based on consultation with the Project Manager.

   i. Be certain that all safety practices and procedures are being followed and that all members of the crew are performing their assigned duties correctly.

   j. Attempt to control the well at the rig site with rig personnel and supervisors.

k. Attempt to construct and/or fabricate and install any well head facilities required to contain fluid flow at the well or casing head.

l. Maintain a continuing inspection of the pad area immediately around the well site subject to erosion that could cause failure to the rig structure. Take necessary steps to avert possible erosion by excavation and rebuilding of the area as necessary.

m. Following complete containment of the well, initiate steps to return the area to its normal state prior to the blowout or fluid flow.

B. Injury Contingency Plan

In the event injuries occur in connection with a PLES operation, specific and immediate attention will be given to proper transportation to a medical facility.

Ambulance Service

Ground - Aegis Ambulance Service
2835 W. Line STreet
Bishop, CA
(619) 873-8904

Mono County Paramedics
Mammoth Lakes (619) 937-3049 or 911
June Lake (619) 648-7234 or 911

Bishop Sierra Ambulance Service
457 W. Yaney
Bishop, CA
(619) 873-4140

Hospital

Centinela Mammoth Hospital
Sierra Park Road
Mammoth Lake, CA
(619) 934-3311

Northern Inyo Hospital
150 Pioneer Lane
Bishop, CA
(619) 873-5811

Mono General Hospital
Bridgeport, CA
(619) 932-7011

C. Fire Contingency Plan

In the event of fire in connection with PLES operations, immediate control attempts and appropriate notifications should be implemented in accordance with the following:

1. Any small fires which occur around the well pad during workovers, drilling or testing operations should be controlled by rig personnel utilizing on-site fire fighting equipment.

2. The Forest Service (619 934-2505) and local fire fighting agency should be notified of any fire, even if the available personnel can handle the situation or the fire poses no threat to the surrounding area.

3. A roster of emergency phone numbers is to be available on site so that the appropriate fire fighting agency can be contacted in case of a fire.

D. Spill or Discharge Contingency Plan

The following plan is consistent with the Emergency Spill containment Plan developed for the PLES I Project. The purpose of this plan is to: (1) identify potential sources of spills; and (2) define emergency response actions which would be initiated by rig and field development crews if a spill should occur during well drilling, testing or servicing operations.

1. Potential Sources of Accidental Spills or Discharges

a. Geothermal Fluid

Accidental geothermal fluid spills or discharges are very unlikely. However, accidental discharges or spills could result from any of the following:

i. Loss of well control (blowout)

ii. Pipeline leak or rupture

iii. Leakage from test tank.

b. Drilling Muds

Muds are mixture of water, non-toxic chemicals and solid particles used in the drilling operations to lubricate and cool the bit, to carry cuttings out of the hole, to maintain the hole integrity and to control formation pressure. Drilling muds are prepared and stored in metal tanks at the drilling site. Waste drilling mud and cuttings are discharged into the reserve pit, which is open and is adequately sized to hold the volume necessary for the operation. Accidental discharges of drilling mud are unlikely, but could occur by:

i. Overflow of the reserve pit.

ii. Reserve pit wall seepage or wall failure.

iii. Discharge from equipment failure on location.

iv. Shallow lost circulation channeling to the surface.

c. Salt Water Kill Fluid

Clear kill fluid is a solution of water and salt which will be necessary to kill some wells for pulling and running pumps or some workover operations. Only those wells which have a standing water level near or above ground level would be expected to require salt water kill fluid. For most such wells, 4,000 gallons or less of 14% (by weight) sodium chloride solution will be adequate. For wells with an unusually high shut-in surface pressure, it may be necessary to use a 30% calcium chloride solution. Specific fluid volumes and salt concentrations must be engineered for each application. These salts are natural components in the geothermal water and, except in the case of an accidental discharge, the kill fluid will be confined to a mixing tank and the geothermal production and injection reservoirs.

Accidental discharges of salt water are unlikely, but could occur by:

i. Loss of well control after the kill fluid was in the well

ii. Discharge from equipment failure on location.

d. Lubricating or Fuel Oils and Petroleum Products

A discharge of this type would probably be very small and be from equipment used in the field. Potential locations for accidental spills are:

i. Drilling equipment and machinery at and around the drilling location.

ii. Other miscellaneous equipment and machinery at well site and roads.

e. Construction/Maintenance Debris

Typically a minor consideration, one which is usually cleaned up on the job. Potential locations are the same as for lubricating or fuel oils listed in Item d, above.

2. Plan for Cleanup and Abatement

In the event of discharge of formation fluids, drilling muds, petroleum products or construction debris, the person responsible for the operation will make an immediate investigation, then contact the Drilling, Workover, or Plant Supervisor (as appropriate) and advise him of the spill. The Supervisor will in turn call out equipment, regulate field operations, or do other work as applicable for control and clean up of the spill, as follows:

a. Action - Small, Containable Spill

If the spill is small (i.e., less than 250 gallons) and easily containable without endangering the watershed, the Supervisor will direct and supervise complete cleanup and return to normal operations.

b. Action - Large or Uncontainable Spill

If the spill is larger than 250 gallons, or is not easily contained, or endangers, or has entered the watershed, the Supervisor will proceed to take necessary actions to curtail, contain and cleanup the spill, as above, and notify personnel as listed below.

c. Notifications

i. The Supervisor will, as soon as practical:

- o Call out contractor(s), as required.
- o Notify the Project Manager.
- o Notify the local law enforcement agencies if the public safety is threatened.

ii. The Project Manager will notify the following as soon as practical and work closely with them in all phases of the curtailment, containment and cleanup operations:

Bureau of Land Management,
Bishop Area Office
873 N. Main St., Suite 201
Bishop, CA 93514
(619) 872-4881

Inyo National Forest
Forest Supervisors Office
873 N. Main St.
Bishop, CA 93514
(619) 873-5841

California Regional Water Quality
Control Board
Lahontan Region - Victorville Office
15371 Bonanza Road
Victorville, CA 92392-2494
(619) 241-6593

Mammoth Ranger District Office
State Route 203
P.O. Box 148
Mammoth Lakes, CA 93546
(619) 934-2505

Project Manager
Pacific Lighting Energy Systems
6055 E. Washington Blvd.
Commerce, CA 90040
(213) 725-1139

The Supervisor will also advise local population and affected property owners if spill affects residents or property.

d. Specific Procedures

i. For geothermal fluid or salt water spills:

- o Contain spillage with dikes, if possible, and haul to approved disposal site by vacuum or water trucks or dispose of in a manner acceptable to the regulatory agencies including, the Regional Water Quality Control Board.

ii. For drilling mud:

- o Repair sump or contain with dikes. Haul liquid to another sump, available tanks or approved disposal site. Dry and solidify remaining material.

iii. For petroleum products:

- o Contain spill with available manpower. Use absorbents and dispose of same in approved disposal area.

For i. through iii. above, Pacific Lighting Energy Systems will have the source of spill repaired at the earliest practical time, and continue working crews and equipment on cleanup until all concerned agencies are satisfied.

e. Confirm telephone notification to agencies and regulatory bodies. Telephone notification shall be confirmed by the Project Manager in writing within two weeks of telephone notification. Written confirmation will contain:

i. Reason for the discharge or spillage.

ii. Duration and volume of discharge or spillage.

iii. Steps taken to correct problem.

iv. Steps taken to prevent recurrence of problem.

E. Emergency Personnel and Telephone Numbers

Fire

Inyo National Forest	Bishop	(619) 873-3300 (Fire only) or 911
	Mammoth Lakes	(619) 934-2505 or 911
Long Valley Fire Dept.	Crowley Lake	934-2200 or 911
Mammoth Lakes Fire Dept.	Mammoth Lakes	911

Law Enforcement

Mono County Sheriff	Mammoth Lakes	(619) 934-6058 or 911
California Highway Patrol		911 or (619) 873-3531

Agency Representatives

U.S. Bureau of Land Management:

District Manager	Bakersfield	(805) 861-4191
Area Manager	Bishop	(619) 872-4881

U.S. Forest Service:

Forest Supervisor	Bishop	(619) 873-5841

Company Representative

Pacific Lighting Energy Systems:

Project Manager	Commerce	(213) 725-1139

CASA DIABLO GEOTHERMAL FIELD

HAZARDOUS GAS CONTINGENCY PLAN

To Be Posted on Rig

Introduction

There is a possibility of encountering noncondensible gases during the drilling of a well. Although noxious or dangerous amounts of noncondensable gases, particularly hydrogen sulfide and ammonia, have not been associated with other wells drilled in the general area, it is necessary to be prepared in the unlikely event of an emergency. It is our intent to provide a safe working environment by taking measures not only to prevent the endangerment of personnel, but also that of public health, safety and the biotic environment.

The possibility of encountering ammonia gas is regarded as extremely remote. In addition, ammonia is considerably less toxic than hydrogen sulfide. Ammonia is included in the contingency plan to provide maximum safety and advance understanding should the improbable event of an emergency situation arise.

The effectiveness of this plan is dependent upon the cooperation and effort of each person who participates in drilling on working on wells. Each individual must know his responsibilities, not only under normal operating conditions, but also under emergency operating situations. Thus all personnel should familiarize themselves with the location and operations of all safety equipment and see that their own equipment is properly stored, easily accessible at all times, and routinely maintained.

General Information

All personnel involved with the mechanics of drilling, evaluating and testing the wells will be trained in the recognition of warning signals, the use of breathing equipment, individual and group responsibilities in case of emergency rescue or first aid, and other emergency procedures.

Each drill site shall have two briefing areas situated so that one would be upwind from the well at any given time. Before drilling begins, all personnel will be advised of an escape route other than the main access road.

A list of emergency phone numbers of personnel and agencies to be contacted in case of an emergency shall be posted in the following places:

1. Drilling Foreman's trailer
2. Drilling crew's dog house

Toxicity of Various Gases

Common Name	Chemical Formula	Specific Gravity(SG) SG Air = 1	Threshold[1] Limit	Hazardous[2] Limit	Lethal[3] Concentration
Hydrogen Cyanide	HCN	0.94	10 ppm	150 ppm/hr	300 ppm
Hydrogen Sulfide	H_2S	1.18	10 ppm[4]	250 ppm/hr	600 ppm
Sulfur Dioxide	SO_2	2.21	5 ppm	-	1000 ppm
Chlorine	Cl_2	2.45	1 00m	4 ppm/hr	1000 ppm
Carbon Monoxide	CO	0.97	50 ppm	400 ppm/hr	1000 ppm
Ammonia	NH_3	0.597	100 ppm	1700 ppm	5000 ppm
Carbon Dioxide	CO_2	1.52	5000 ppm	5%	10%
Methane	CH_4	0.55	90000 ppm	Combustible - above 5% in Air	

[1] Threshold Limit - Concentration at which is is believed that all workers may be repeatedly exposed day after day without adverse effects.

[2] Hazardous Limit - Concentration that may cause death.

[3] Lethal Concentration - concentration that will cause death with short-term exposure.

[4] Threshold Limit = 10 ppm - 1972 ACGIH (American Conference of Governmental Industrial Hygienists).

[5] Threshold Limit = 20 ppm - 1966 ANSI acceptable ceiling concentration for eight-hour exposure (based on 40-hour week) is 20 ppm. OSHA Rules and Regulation (Federal Register, Volume 37, No. 202, Part II, dated October 18, 1972).

Physical Effects of Hydrogen Sulfide

Percent	0 to 2 Minutes	15 to 30 Minutes	30 Minutes to a Hour
0.001 (10 ppm)- 0.002 (20 ppm)	Detectable by "rotten-egg" smell.	Detectable	Detectable. Maximum allowable concentration for 8-hour exposure without protective mask
0.01 (100 ppm)	Coughing, slight irritation of eyes. Loss of sense of smell.	Disturbed respiration. Pain in eyes. Sleepiness	Throat and eye irritation
0.025 (250 ppm)	Loss of sense smell.	Throat and eye irritation.	Throat and eye irritation.
0.035 (350 ppm)	Irritation of eyes. Loss of sense of smell.	Irritation of eyes and respiratory tract.	Painful secretion of tears, weariness; may cause death in longer exposure.
045 (450 ppm)	Irritation of eyes. Loss of sense of smell.	Difficult respiration. Irritation of eyes.	Increased irritation of eyes and nasal tract. dull headache. Serious respiratory disturbance.
0.09 (900 ppm)	Coughing, unconsciousness. Serious respiratory disturbances.	Respiratory disturbances. Eye irritation. Unconsciousness.	Serious eye irritation. Slow pulse, rapid shallow breathing. Respiratory paralysis, convulsions, asphyxia and death.
0.10 (1000 ppm)	Unconsciousness.	Death	Death.

Physical Effects of Ammonia Gas

Concentration		Physical Effects
Percent (%)	PPM	
0.005	50	Odor detectable. Prolonged repeated
0.01-0.02	100-200	No adverse effect for average worker. Exposure produces some discomfort but no lasting effects.
0.03-0.07	300-700	Produces nose and throat irritation and eye irritation with tearing. Exposure should be avoided but usually no serious after effects with short infrequent exposures.
0.17-0.30	1700-3000	Produces convulsive coughing and severe eye irritation. Dangerous for even short exposure. May be Fatal.
0.5-1.0	5000-10,000	Produces respiratory spasm; rapid asphyxia. Exposure is rapidly fatal.

Safety Procedure, Equipment and Training

The following procedures apply primarily to drilling operations. For operations on existing wells which are known to not have dangerous concentrations of hazardous gases, the procedures relating to hazardous gases may be eliminated.

Training Program

A scheduled training program for all personnel and supervisors will be conducted at the beginning of the drilling program and for new hires on their first day of work. This program will assure that all personnel will be familiar with the location and proper use of safety equipment. They will be informed of prevailing winds, briefing areas, and evacuation procedures.

Equipment:

The drill site will be equipped with the following safety equipment for H_2S detection and personnel safety:

1. First aid kit, sized for the normal working number of. personnel.
2. Stokes litter, or equivalent.
3. Wind direction indicating equipment at prominent locations.
4. Protective breathing apparatus of OSHA Standard for the working crew (Minimum of 2).
5. Wind socks or streamers, positioned to be readily visible from the rig floor and both briefing areas during both night and day.
6. Portable hand operated hydrogen sulfide detectors. These can also be utilized for detection of sulfur dioxide and ammonia. H_2S, SO_2 and NH_3 detector ampules will be readily available for spot checks.

There shall also be an adequate supply of H_2S scavenger chemicals on site to treat the mud system, should the mud become contaminated with hydrogen sulfide.

Warning signs will be available for posting on the access road to the location.

Drills

Drills with breathing equipment will be conducted for each crew, including the mud loggers and mud engineer. Each crew member will be instructed in utilization of the protective breathing apparatus.

Procedures for Operating Conditions

The Drilling Foreman or, in the event he is not present, the Drilling Contractor Tool Pusher in charge of the working crew will have full responsibility for safety precautions and will direct operations necessary to the safety and health of all personnel on the drill site.

Normal Operating Conditions

Prior to drilling into the first zone suspected of possible H_2S gas, all personnel will be instructed on the hazards of H_2S, and the location and the use of safety equipment onsite. They will also be informed of the H_2S monitors, their locations and the related alarm system along with the ventilation equipment, prevailing winds, briefing areas, and evacuation procedures.

Subsequent to penetrating into a possible H_2S bearing zone, a meeting will be held covering the above if not previously held.

Upon drilling into any suspected H_2S zone, the evolved gas will be monitored at the shaker. Should H_2S be present in concentrations between 10 ppm to 20 ppm, all personnel shall be advised.

H_2S and NH_3 Emergency Conditions

After H_2S and NH_3 have been detected, operations will proceed as follows:

Condition I - Potential Danger

Routine checking of the drilling fluid and the monitoring equipment will alert the mud loggers to the presence of hydrogen sulfide in concentrations less than 10 ppm. The mud loggers will notify the Drilling Foremen of the hydrogen sulfide concentrations. No danger to personnel exists as long as H_2S concentration remains below 10 ppm.

General Actions:

1. Personnel will be alert for any changes in H_2S concentrations.
2. All safety equipment, monitors and alarms will be checked for proper functioning.
3. Drills and review of emergency programs will be conducted.

Condition II - Moderate Danger

When H_2S concentration reaches 10 ppm.

General Actions:

1. All personnel on the rig and in the area of the mud pits will be advised to put on their breathing equipment.
2. The Drilling Foreman and the Drilling Engineer will be notified. Their instructions will be followed.
3. Steps to locate the source of H_2S will begin immediately. Required steps to suppress the H_2S will be taken. Drilling will not proceed until the source is determined, the well circulated, and the gas controlled.
4. All nonessential personnel will be sent out of the potential danger area.
5. All gas monitoring devices will be checked and gas monitoring activities with the portable hand operated gas detector unit will be increased.
6. The Drilling Engineer and Drilling Foreman will assess the situation, outline a control program, and assign duties to each person or group as required to bring the situation under control.
7. Access to the drill site will be limited to authorized personnel only.
8. If the H_2S concentration should rise to 20 ppm, warning signs will be posted on the access road(s) to the location indicating:

"DANGER - POISONOUS GAS"

"HYDROGEN SULFIDE - H_2S"

Condition III - Extreme Danger to Life:

This condition is reached when one or more of the following occurs: well control problems, poisonous gas exceeds threshold levels (as defined under "Toxicity of Various Gases"), and loss of well control.

1. All personnel will put on protective breathing equipment.
2. All personnel not required for well control or with perforated eardrums will proceed to the upwind briefing area for evacuation instructions.
3. The Drilling Engineer and Drilling Foreman will assess the situation, outline a control program, and assign duties to each person or group as required to bring the situation under control.
4. Any steps necessary and feasible to minimize environmental impacts will be taken.
5. The agency representatives will be notified.
6. If there is no hope of containing the well under prevailing conditions, and there is a definite threat to human life and property:
   a. The Emergency Plan will be initiated.

   b. The Blowout Action Plan will be referred to and followed.

   c. If all else fails, the well will be ignited. Instructions for igniting the well are as follows:

      i. Two people are required for the actual igniting operation. Both people will wear self-contained breathing units and will have 200' retrieval ropes tied around their waists. One person is responsible for checking the atmosphere for explosive gases, the other is responsible for lighting the well. Personnel not assigned special duties will be kept within the safe briefing area. Those in the safe briefing area will be alert to the needs of the two people assigned to ignite the well. Should either of these people be overcome by fumes, they will immediately pull then to safety by the retrieval ropes.

      ii. The primary method for igniting the well is a 25 mm meteor type flare gun. It has a range of approximately 500'. If this method fails or well conditions are such that a safer or better method is apparent, then the alternate should be used.

iii. If the well is ignited, the burning hydrogen sulfide will be converted to sulfur dioxide which is also poisonous. Thereafter, DO NOT ASSUME THAT THE AREA IS SAFE AFTER THE GAS IS IGNITED. CONTINUE TO OBSERVE EMERGENCY PROCEDURES AND FOLLOW THE INSTRUCTIONS OF SUPERVISORS.

d. Initiate the program to kill, plug and abandon the well.

Emergency First Aid Procedures

While extensive preparations for personnel safety have been made, all personnel should be aware of first aid procedures in the event of an accident. First aid for H_2S and/or NH_3 victims is based primarily on moving the victim to fresh air immediately.

1. Warning - Do not jeopardize your own safety. Always wear a self-contained breathing apparatus while attempting rescue.

2. If people are trapped or unconscious in an ammonia vapor cloud, the ammonia vapor in their immediate area can be reduced considerably by use of a water fog or spray. Since ammonia is water soluble, a water fog or spray is effective in removing the gas from the surrounding atmosphere. a fog nozzle can be attached to a fire hose and the fire hose turned on, playing the stream of spray or fog through the ammonia vapor to form an ammonium hydroxide (NH_4OH) fog, which condenses as it cools and will fall to the ground. This technique could also be used to protect personnel trying to approach a leaking line or valve to make repairs or shut down equipment.

3. If a victim is unconscious and not breathing, immediately move the victim to a safe breathing area and apply an approved method of artificial respiration, continuing without interruption until normal breathing is restored.

4. Symptoms may pass rapidly, but keep the victim warm and transport him to a hospital under the care of a physician as soon as possible.

CASA DIABLO GEOTHERMAL FIELD

BLOWOUT ACTION PLAN FOR DRILLING AND WORKOVERS

To Be Posted on Rig

1. The hole is to be kept full of drilling or completion fluids at all times unless this becomes impossible due to lost circulation.

2. Before starting out of hole with drillpipe or tubing, circulate off bottom until mud is properly conditioned.

3. Close and open rams and annular preventer once per day and log on tour sheet. Pressure test BOPE prior to drilling out of casing shoes and coincident with casing test. Log results on blowout preventer check list.

4. Close blind rams or master valve when out of hole and log on tour sheet.

5. Fill hole at five (5) stand intervals or less while pulling drillpipe out of hole. Count pump strokes or use chart attached to the pit volume indicator to determine the volume required to fill the hole.

6. Watch pit flow or pit level indicator when running in the hole to insure that the volume of mud displaced by the drillpipe is not exceeded.

7. The drillpipe will be run in the hole to the shoe of the casing with the inside BOP installed to perform any of the following operations:

   a. Slip and cut drilling line.
   b. Repair equipment (if possible).
   c. Any foreseen delay.

8. Record reduced circulating pressure at 30 strokes per minute (SPM) or other suitable kick control SPM daily and after each bit change.

9. An approved inside blowout preventer and full opening safety valve with wrench must be immediately available on the rig floor.

10. A blowout prevention drill will be conducted by the rig tool pusher under the supervision of the Drilling Supervisor for each drilling crew to ensure that each person is properly trained to carry out emergency procedures. Assign kick control duties in advance: i.e., mud mixing assigned to floorman, operating pumps assigned to derrickman, etc.

11. At first indication of gain in pit level (or other sign of possible blowout), the driller will immediately do what is necessary to control the well. In most cases this action should be:

While Drilling:

a. Pull kelly up out of rotary table and stop pumps.

b. Open valve(s) on choke line.

c. Close the blowout preventer and gradually reclose choke line.

d. Record shut-in drillpipe (Pdp) and casing (Pcg) pressure. Maximum allowable casing pressure to be dependent on casing depth and burst rating. Allowable pressure for each string to be posted and noted in driller's instructions and on well control data sheet.

e. Inform the Drilling Supervisor and/or proceed with appropriate kick control measures as follows in Step 12.

While Tripping:

a. Install full opening safety valve.

b. Open valve on choke line(s).

c. Close safety valve.

d. Close blowout preventer and gradually reclose choke valve(s).

e. Record shut-in drillpipe and casing pressure. Maximum allowable casing pressure to be dependent on casing depth, mud weight and burst rating.

f. Inform the Drilling Supervisor. Run drillstring in hole as far as practical after first installing inside BOP and reopening safety valve, and/or proceed with appropriate kick control measures as follows in Step 12.

12. Open choke line. start pump and run at 30 SPM or other previously set SPM while adjusting choke line valve to set drillpipe circulation pressure equal to normal circulation pressure at 30 SPM or other previously set kick control SPM. plus shut-in drillpipe pressure.

13. Calculate and mix mud of weight necessary to keep well under control using the well control worksheet and attached nomograph.

Mud weight increase in lb/ft3 =

$$\frac{\text{Pdp} \times 144}{\text{Drillstring depth in feet}} + 3 \text{ lb/ft3}$$

Where Pdp = shut-in drillpipe pressure in psi.

14. When sufficient volume of proper weight mud has been prepared, start pumping the weighted mud through the drillpipe at constant kick control SPM which will reduce circulating pressure downward gradually from Pi (initial drillpipe circulating pressure) as calculated on the well control worksheet to Pf (final drillpipe circulating pressure) when drillpipe is filled with weighted mud. Thereafter, hold drillpipe pressure constant at Pf by adjusting choke valve until properly weighted mud returns to surface.

15. When properly weighted mud returns to surface, stop pumps, release any remaining pressure on casing, and check for additional kick before returning to normal operations.

16. Drill new directional hole as a last resort to kill well.

CASA DIABLO GEOTHERMAL FIELD

BLOWOUT ACTION PLAN FOR PULLING AND RUNNING PRODUCTION WELL PUMPS

To Be Posted on Rig

1. The well will be killed and kept dead during the running and pulling operations by one of the following methods:

   a. For wells which are known to have a standing water level below ground level, maintain a flow of cool, fresh water into the well.

   b. For wells which are known to have a standing water level near or above ground level, kill the well with salt water and monitor the water level frequently. Maintain an adequate supply of salt on location and inject more kill fluid if necessary to keep the well dead.

2. A safety valve will be kept on the rig platform at all times and will be used to shut in the column pipe: (1) in the event of a delay in the pulling or running operation; (2) when the well is unattended; and (3) to control a blowout.

3. Use a double ram BOP on the well. Close and open pipe rams once each shift and log on the tour sheet.

4. Close blind rams when pump is out of the hole.

5. Close pipe rams: (1) in the event of a delay in the running or pulling operation; (2) when the well is unattended; and (3) to control a blowout.

APPENDIX B

LANDSCAPE AND REVEGETATION MASTER PLAN

LANDSCAPE AND REVEGETATION MASTER PLAN

FOR

PLES I
GEOTHERMAL PLANT

February 15, 1988

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INTRODUCTION

This Landscape and Revegetation Master Plan is the result of intensive research and field study. The intent of the Master Plan is threefold:

1) To mitigate the visual impacts of the proposed geothermal plant, well sites and pipelines;

2) To restore disturbed areas to their natural state; and

3) To control erosion and sedimentation.

Many resources (i.e. California Department of Transportation, U.S. Forest Service, Bureau of Land Management, U.S. Soil Conservation Service, etc.) have been consulted in forming methodologies to achieve these goals. Much of the information obtained from these resources is included as background and substantiation for these methodologies and can be found as exhibits.

The plant site, well sites and each stretch of pipeline have been evaluated regarding impact upon their immediate surroundings, and the most appropriate solutions specified. Photographs are provided where possible to familarize the reader with each area. We are confident that the proposals specified in this report and accompanying plans provide practical and responsive solutions to a complex and challenging project.

METHODOLOGIES

Several methodologies are repeated throughout the plan. These methodologies are used in different combinations, depending upon each area and its specific needs. A brief description of each methodology and its basis for inclusion follows.

Stockpiling of Topsoil

The plan specifies that topsoil will be stockpiled from all graded areas. The top 4 to 6 inches of soil including all plant material is to be scraped off before grading. The included plant material is to be disked, shredded or chopped into pieces no larger than 6 inches. Topsoil and duff is then stockpiled in windrows during construction. After disturbed areas have been recontoured as per the civil engineering specifications, the topsoil and duff shall be spread at a depth of approximately 4 inches. According to Caltrans studies (See Exhibits A, B and C), this procedure has been very successful in providing a planting bed for seedlings with a bank of seed from the native vegetation which allows for the rapid re-establishment of native flora.

Mulching

Mulching of seeded areas increases germination rates while also decreasing runoff and erosion. All seeded areas are to be mulched by one of several methods:

1) All slopes of 4:1 or less shall be mulched with straw spread at a rate of 2 tons per acre.

2) All slopes of 3:1 are to be covered with a straw erosion control blanket #S150.

3) All slopes of 2:1 or greater are to be covered with a

straw erosion control blanket #SC130.

High winds in the plant area make mulching difficult. For this reason, a straw blanket method has been selected for significant slope areas. Straw erosion control blankets afford immediate cover that is not subject to being blown away. The U.S. Forest Service is enthusiastic about using this material but recommends an alternative staking detail for the volcanic soil types in the plant area. The manufacturer has recommended specific blanket types and will have a representative present for the initial installations (See Exhibit P).

Seeding

After the topsoil and duff has been spread over disturbed areas, these areas are to be seeded with a mix of grass and shrub seeds as follows:

15%	Artemisia tridentata	Sagebrush
15%	Purshia tridentata	Bitterbrush
10%	Orysopsis hymenoides `Nespar´	Indian rice grass
20%	Elymus cinereus	Great Basin wild rye
20%	Agropyron desetorum `Nordan´	Crested wheat grass
20%	Agropyron trichophorum `Mandan´	Pubescent wheat grass

While various seed mixes were considered (See Exhibit D), the consulting biologist has determined that the above mix would be the best for both controlling erosion and re-establishing a native stand (See Exhibit E).

After seeding a 20-20-20 fertilizer shall be applied at a rate of 350 pounds per acre. This is in keeping with the Environmental Impact Report recommendations (See Exhibit F).

Seedling Plantings

In some areas additional planting of shrub seedlings are specified. These seedlings are to be contract grown from locally collected seed. Caltrans has completed extensive testings of native shrub planting and concludes that, "The use of container-grown native shrubs for transplanting in Eastern Sierra roadsides appears highly feasible" (Exhibit G).

The shrubs to be grown and planted include:

45% Artemisia tridentata	Sagebrush
30% Purshia tridentata	Bitterbrush
15% Chrysothamnus nauseosus	Rubber rabbitbrush
10% Prunus andersonii	Desert peach

Percentages and spacings are designed to match natural plant distribution as closely as possible. Caltrans and the U.S.F.S. have also had success with plantings of Jeffrey pine (Pinus jeffreyii) seedlings (Exhibit C). Reforestation with pine seedlings is specified in some of the more heavily forested areas of this project. Timing of seed collection, seedling planting and propagation techniques have been addressed in the specifications as per recommendations of Caltrans (Exhibits H, I and J) and the U.S.F.S. (Exhibit K).

The contractor is required to guarantee a success rate of 70% for a five year period. This is within the range of success on Caltrans plantings.

Container Grown Plantings

In some areas, plants larger than seedlings are recommended for visual mitigation. Careful consideration has been given to selecting plants which are native to the Eastern Sierra area. Since the availability of nursery-grown natives is somewhat limited, a strict adherence to the "natives only" rule seems impossible. Rate of growth, screening properties and availability were also factors in plant selections (See Exhibits L and M).

Container-grown plantings include:

Ribes cereum - Squaw currant
Salix exigua - Native willow
Rosa woodsi - Wood rose
Amelanchier alnifolia - Serviceberry
Pinus jeffreyii - Jeffrey pine
Quercus vaccinifolia - Huckleberry oak

Tree Spade Transplanting

An important part of the landscape plan involves transplanting native pines from one location on the site to another. Trees of appropriate size and accessibility are in abundance on the areas slated to be graded. In addition, soils reports indicate favorable soil structures for this operation in most areas.

The obvious advantage to transplanting is immediate visual mitigation and the opportunity to use native, site-adapted plant material. While it does not appear that this type of operation has taken place previously in the Mammoth area, tree spade transplanting has been very successful elsewhere in the Eastern Sierra (See Exhibits N and O).

Transplanted pines range in height from 8 to 20 feet and will be guaranteed for a period of one year. Locations have been selected to conceal plant facilities from the immediate view, as well as the distant view.

Irrigation

Irrigation to seeded and planted areas is provided to ensure seed germination and successful establishment of seedlings and container-grown stock. A temporary overhead system will be installed as indicated on the plans. This system will remain in place for at least a two year period for appropriate establishment of vegetation.

A permanent drip irrigation system will be installed to container-grown stock and transplanted specimens. Water usage will be kept to a minimum.

Painting

Colors will be selected for painting of pipelines and other structures. These colors will blend with the natural occurring tones in each specific area. Camouflage techniques are recommended in some areas, involving the use of several colors to create a texture or pattern more in keeping with the natural surroundings.

Trenching

Although more expensive than other techniques, laying pipe in trenches is recommended in some areas which are especially visually sensitive. Trenching ensures that the visual impact of pipelines, in selected areas, is mitigated from the onset. Erosion control and revegetation is specified on all areas disturbed by trenching.

Retaining Walls

Where the new grade encroaches significantly into the drip line of existing trees, retaining walls are included. These walls ensure the survival of many existing trees which would otherwise need to be removed.

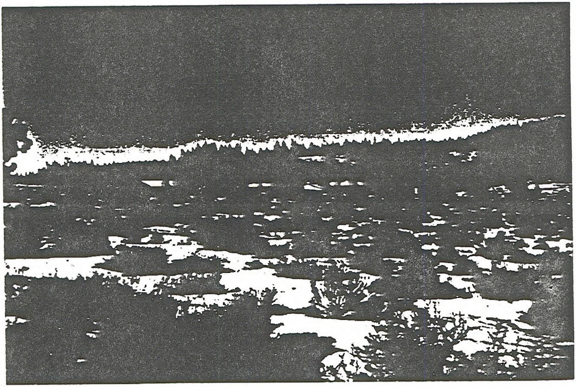
WELL SITE AND PIPELINE TREATMENTS

Pipeline Sections P-A, P-B, and P-C, Well Sites SF 25-32, SF 35A-32, SF 34-32

All of these improvements run through relatively level terrain to the south and east of the existing plant. This terrain is well covered with a mix of bitterbrush, sagebrush, rabbitbrush and desert peach as well as scattered Jeffrey pine. Seeding and seedling planting should restore disturbed areas to this state.

Transplanted Jeffrey pines will help to buffer pipelines and well sites in this area from adjacent roads (Highway 203 and Old 395). The view from Highway 395 into these facilities as well as the existing plant will also be broken by these tree plantings.

Pipelines and well heads should be camouflage painted in sage green and sand brown.

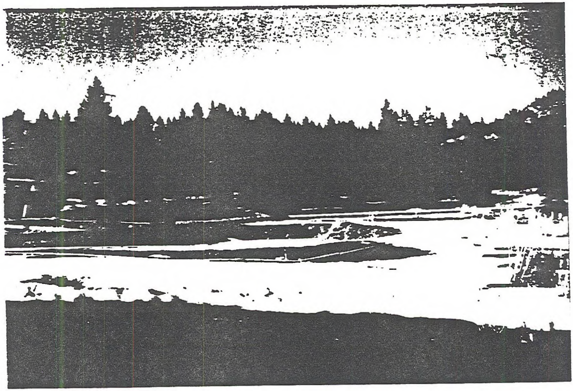


Pipeline Section P-D

This area was previously graded for drainage sumps. The current plan calls for these sumps to be filled and revegetated. Level terrain and proximity to Old 395 make this section of pipe highly visible.

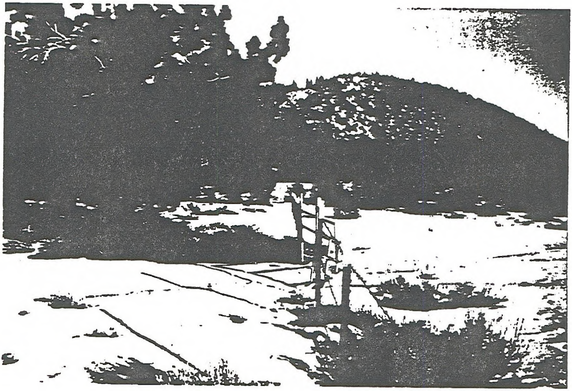
Plantings of native willow (Salix exigua) will modify these visual impacts. Natural drainage patterns in this area should help make these plantings successful.

Additional plantings of ponderosa pine and serviceberry in the drier areas will also help to conceal the pipe.



Pipeline Section P-E

This section is highly visible, as it runs parallel to Old 395 through sparsely vegetated terrain. For this reason, pipe trenches have been designed for immediate concealment of pipes. All disturbed areas are to be seeded and revegetated with seedlings.



Pipeline Section P-F and Well Sites SFI 54A-32, SFI 54-32, SFI 64-32

This area is surrounded by heavy tree cover and removed from roads or other visual access points. The need for visual mitigation is therefore minimal. All disturbed areas are to be seeded and planted with Jeffrey pine seedlings.

Pipelines and well heads should be painted with a dark grey-brown tone to blend with the soils and tree trunks.

PLANT SITE LANDSCAPING

The plant site is located in a relatively well-forrested area about 600 feet from Old 395. Existing tree cover will help to mitigate visual impacts. Additional transplanted pines have been specified in clearings. These transplants will help to fill views into the plant site. Some trees have been placed relatively close to the road at critical vantage points.

Fill slopes to the south of the plant will be seeded and planted with native shrub and Jeffrey pine seedlings.

The control room building will be landscaped with shrubs.

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INTRODUCTION

The following report is in the form of an appendix due primarily to its length and, in part, to its technical nature. The discussion in the main body of the joint EIR/EA on hydrology was necessarily generalized, and summarizes the data and conclusions contained in this appendix. The important issues concerning potential impacts of geothermal power projects by production to both thermal and non-thermal water in the southwest caldera area require a more rigorous approach and analysis than is usually needed for such an environmental review. While there is no way to precisely predict potential impacts on the hydrologic system on the basis of current data, utilization of the models allow an analysis of reasonably likely potential impacts.

Although a considerable amount of data directly and indirectly related to the hydrologic system has been and is continuing to be collected by governmental agencies and industry, the exact nature of the hydrologic system and how the subsurface system and the surface features are interrelated cannot be defined at this time. However, sufficient information is available to develop reasonable scientific models of the system.

This report is not intended to replace or subsititute for an environmental document in format or content. It is intended as supplemental information. Refer to the main EIS document or related EIR/EA documents for details on issues, impacts, proposed mitigations and their effectiveness.

1.0 AFFECTED ENVIRONMENT

1.1 Overview of Hydrothermal System

Hydrothermal activity is believed to be present throughout the Long Valley caldera, but is most apparent in terms of surface manifestations and shallow, high temperature zones in the south and southwestern region. This includes the area bounded by Casa Diablo Hot Springs to the west and Hot Creek Gorge to the east.

The complex fault-controlled geologic structure and thermal fluid distribution has been subject to study for many years, but is not clearly understood. Identification of the origin of the thermal fluids in each of the areas of concern (Casa Diablo, Fish Hatchery, and Hot Creek Gorge) is important for an understanding of whether increased production at Casa Diablo will affect surface or subsurface hydrologic features.

A variety of methods have been used by numerous investigators in an attempt to characterize the hydrothermal system. These investigators include geologists, reservoir engineers, geochemists, hydrologists and geophysicists from both government agencies and private industry. Many of the studies referenced were conducted for purposes other than to assist in the development of a hydrologic model. For example, several monitoring programs were begun in an attempt to detect changes due to subsurface magmatic activity and the possibility of a near surface magma chamber. All of them have contributed to a growing data base from which to compare past, present and future changes occuring within the Caldera hydrologic system.

1.2 Surface Resources

Surface resources in the south and southwest Long Valley area include cold water streams and numerous springs of varying temperatures. The PLES I Project area is located in the Mammoth/Hot Creek drainage basin. The springs at issue are located in three general areas: 1) at Casa Diablo near the proposed PLES I site; 2) the Hot Creek Fish Hatchery area; and 3) the Hot Creek Gorge area. The Colton Spring area is also of interest. It is located between the proposed project area development and spring groups of concern. This spring is of interest due to potential use for monitoring the hydrothermal system and will be discussed in some detail.

1.2.1 Creeks & Surface Drainage

The major surface water features in the Western Long Valley area are shown in Figure 1-1. The Owens River is the major drainage feature for the entire Long Valley Area with tributaries from several major drainage basins of which the Mammoth Basin is one. The Mammoth Basin contains Mammoth/Hot

Creek and a few lesser tributaries. Mammoth/Hot Creek carries all surface drainage from the Mammoth Basin to the Owens River. The Owens River discharges to Crowley Lake approximately nine miles southeast of the Project area.

The primary surface drainage feature in the PLES I Project site is an unnamed ephemeral tributary to Mammoth Creek (Figure 1-2). This creek originates near U.S. Highway 395 approximately 0.5 miles northwest of the Casa Diablo area and joins Mammoth Creek approximately 0.4 miles southward.

The intermittent stream discharge rate varies seasonally from zero to approximately forty cubic feet per second. (See Table 1-1 for a comparison with flows of Mammoth/Hot Creek.) Flow rate and fluid chemistry are affected by the relative contribution from the Casa Diablo Hot Springs located nearby. In years with above normal late season precipitation this tributary to Mammoth Creek flows year-round. Yearly and seasonal variations in snow and rainfall amounts are the major cause of fluctuations in the flow of this stream. A significant, though unmeasured, amount of creek flow is believed lost into the thin alluvium between Casa Diablo and Mammoth Creek.

There is no published chemical analysis available for the waters of this tributary. However, such an analysis would be likely to show a considerable variation in mineral content depending upon the relative influx of hot spring waters and seasonal changes associated with runoff.

Biological contaminants (e.g., fecal coliform) as a result of seasonal cattle grazing probably render the creek waters unfit for human consumption even during high flow periods. No such consumptive use of the tributary currently exists or is planned. The intermittent stream through Casa Diablo joins Mammoth Creek at a small meadow between new U.S. Highway 395 and old Highway 395. Intermittent stream waters mix with Mammoth Creek at this point allowing potential contaminants to be carried downstream to Hot Creek and eventually to Crowley Lake.

The flow in Mammoth Creek has been monitored since 1932 by LADWP at a flume (MCF) a short distance downstream from the inlet of the intermittent stream as shown on Figure 1-3 (California Department Water Resources; 1967, 1973). Discharge rates measured at this point vary between 3,000 to 40,000 acre-ft/year and average approximately 17,000 acre-ft/yr. The quality of the water in Mammoth Creek is generally very good above U.S. Highway 395, but begins to degrade as hot spring discharge and grazed land runoff contaminants increase downstream (Setmire, 1984). Table 1-2 is a summary of selected measurements indicative of seasonal changes in the Mammoth Creek flow and quality. These measurements show that a portion of the flow is lost to shallow ground waters in the meadow area between

U.S. Highway 395 and the Hot Creek Hatchery. An unknown quantity is diverted during summer months by a local rancher which may account for some or perhaps all of the loss, depending upon the time of year.

Hot Creek begins at the confluence of Mammoth Creek and the effluent from the spring groups supplying the Hatchery. Effluent from the Hot Creek Hatchery contributes approximately 17-28 cfs to the flow of Hot Creek. The flow rates shown in Table 1-2 reflect surface drainage contributions to the creek (Sorey, 1976) (Farrar, 1985). Depending upon daily operations at the Hatchery, a short term increase in some chemical constituents from Hatchery operations may be introduced to Hot Creek with the spring effluent (personal communication, Hot Creek Hatchery manager, 1987). Since this additional volume of flow enters below the Hatchery, its contribution to total stream flow is not continuously measured except as total stream flow at the flume at Hot Creek Gorge (HCF). The Hatchery springs and chemistry are discussed in a following section of this report.

The last point of measurement for surface waters from the Mammoth Basin area is at the flume below Hot Creek Gorge (HCF). This site has been used to gauge stream flow since 1923 and has most recently been used to estimate the rate of discharge from the Hot Creek Gorge springs relative to total stream flow.

Stream flow at this flume (shown as HCF on Figure 1-3) varies between 25,000 to 80,000 acre-ft/year and averages approximately 40,000 acre-ft/year (CDWR, 1967). Of this total 7,000 acre- ft/year (average 9.5 cfs) are contributed by thermal springs in the gorge (Farrar, 1985). Chemical analysis of water samples taken at the flume indicate most of the dissolved mineral load is due to discharge from thermal springs along Mammoth/Hot Creek (CDWR: 1967, 1973) (Setmire, 1984). As Table 1-2 shows, the temperature and conductivity of Mammoth/Hot Creek increase downstream as the various springs join the total flow. Under the present conditions, the quality of the water in Hot Creek at this point (HCF) may not be suitable for human consumption (Setmire, 1984).

1.2.2 Thermal Springs

Numerous hydrothermal features are located between the Casa Diablo area, near the proposed PLES I Project site, and the Hot Creek Gorge area (Figure 1-3). These hydrothermal features consist of springs, with various temperatures and discharge rates, and gas emitting fumaroles. Some of these features maintain a relatively constant level of activity from year to year. Others are known to be intermittent.

1.2.2.1 Casa Diablo

There are several surface thermal features in the Casa Diablo area, and most are located to the west of the PLES I Project area (Figures 1-2 & 1-3). The discharge rates, chemistry and temperature of these features may be closely related to the subsurface hydrothermal conditions.

Though the main surface features near Casa Diablo are on private land, the geothermal developers are aware of the potential relationship between springs and subsurface conditions and have cooperated in the monitoring of the Casa Diablo springs and fumaroles by the U.S. Geological Survey (Farrar, 1985, 1986). The monitoring consists of periodic sampling of several vents, and spring discharge measurement of the main feature, referred to as the Casa Diablo Geyser (CDG). While minor interruptions of flow rate measurements have occurred due to equipment problems, and the results thus far show a distinct correlation between spring discharge and tectonic strain events, as shown by the large increase in flow rate three weeks before a November 1984 earthquake of magnitude 5.8 nearby (Figure 1-4). A less distinct correlation is shown in the 1985 data between existing geothermal well production and total spring discharge, including CDG and two lesser springs (Figure 1-5). The period mid-March through mid-August (1985) shows a possible relationship, but is not consistent through the latter part of the year. The spring ceased to flow in April, 1987.

These more recent events are similar to historical accounts which date back to the late 1800's reporting a wide range of activity from "geysering" 10's of feet high to no visible discharge (LBL, 1984). Recent estimates of total spring discharge vary from 0 to 1.4 cfs with most of the flow from the main vent (CDG). Temperatures between springs vary, with conductive cooling having a greater effect on low flow rate features. The temperature measurements range from 80° to 94°C (Table 1-3).

Chemical analyses can be of use when attempting to correlate the source of spring waters emanating from each feature to subsurface conditions. Hot spring fluid chemistry is characterized as sodium bicarbonate-chloride waters with a total dissolved solids content of 1000 to 1400 mg/l. The data in Table 1-3 indicate the chemistry of each spring is affected by discharge rate and temperature as boiling in the near-surface concentrates constituents in the fluid, which may then partially re-mix with condensate. Published analyses also indicate a complex relationship with possible mixing of cooler less saline shallow groundwaters (Mariner & Wiley, 1976). Efforts at correlation have been based on comparison of prominent chemical species that are conserved during mixing and boiling, such as:

Chloride (Cl), Lithium (Li) and Boron (B) (Table 1-3).

Data in Figures 1-6 and 1-7 of Cl/B and Cl/Li ratios indicate that the ionic ratios, as indicated by the straight line, are similar between the various areas. The data also shows a trend of decreasing ionic concentration away from Casa Diablo, but with ionic ratios preserved (Shevenell, et al, 1987 in print). These data have been used to support models describing a shared source of fluids for the Casa Diablo springs, Hot Creek Gorge and Hatchery springs. A more complete description of the hydrothermal system model based upon chemistry data is given in the Subsurface Resources Chemistry section, below.

Stable isotope data is plotted in Figure 1-8, for the springs identified in Figures 1-6 and 1-7. Large isotope differences are apparent between the Casa Diablo springs, deep wells, and CDG. Figure 1-8 data suggests a more complex thermal fluid chemistry than can be accounted for by simply assuming dilution of thermal waters with non-thermal fluids. A combination of boiling and mixing of thermal and non-thermal fluids is required to explain the isotopic data. Though there exists controversy amongst experts as to whether the conditions required to achieve the composition, by this mechanism, exist. These results were then used to support a lateral flow model based on a shared fluid source.

Another explanation has been proposed based on upwelling along fault zones. This upwelling/fracture flow model attributes differences in isotope chemistry between the thermally active areas to each having a different origional metoric source of fluid that is upwelling from near or in deep basement rocks (Mesquite, 1986). A more detailed explanation of this theory is given in the comments included in the Final EA/EIR for the PLES-I project.

1.2.2.2 Colton Spring Area

This area consists of three groups of small springs located approximately one mile southeast of Casa Diablo along Mammoth Creek. Their combined discharge is small and the water is not currently used in any way, although they contribute to the flow of Mammoth Creek. However, their markedly different temperatures and chemical compositions are of interest in attempting to define the local hydrothermal system and to determine whether changes due to increased production at Casa Diablo will extend to the Colton Spring area.

Colton Spring (CS in Figure 1-3) may be affected by the same tectonic processes that affect the Casa Diablo Springs. Colton Spring appeared suddenly at approximately the same time as a large scale seismic event in 1980. Its discharge, estimated at 0.021 to 0.029 cfs between August and December 1985, may fluctuate due to natural causes. The temperature (92.9° to 93.8° C), and chemistry (Table 1-3) are very similar to CDG.

Meadow Spring, located in the meadow southwest of old Highway 395, is cooler (52.2° to 62.5° C) with low, intermittent discharge. The chloride content and ionic ratios (Table 1-3, Figures 1-6 and 1-7) of Meadow Spring suggest that it could result from mixing of waters similar in composition to CDG and that of local, near-surface ground water. The choice of a chemical composition to use as representative of cold fluid for mixing models can significantly affect results and is therefore the subject of some debate. Cooler shallow groundwater is likely to have several sources of recharge, depending upon the specific area in question (e.g. meteoric water, local stream leakage, migration in shallow subsurface from nearby mountains, etc). These may have similar low levels of mineral constituents, but not necessarily similar isotopic concentrations.

Chance Spring (CHS on Figure 1-3), with a temperature of 18° to 20°C, issues from a group of vents along Mammoth Creek. It has a relatively high discharge (approximately 0.81 cfs), and a chemical composition closer to that of meteoric water than other nearby springs, suggesting a small thermal water component. Chemical analyses are not performed at regular intervals and are not presented in Table 1-3. Two analyses (one in 1963 and one in 1984) are presented in Table 1 of Farrar, et al (1985).

1.2.2.3 Hot Creek Fish Hatchery Area

The four major spring groups in the hatchery area, AB, CD, H-I and H-II, III (also denoted as H-1 and H-2,3), discharge from the edge of a basalt flow (Figure 1-9). These are the principal sources of water for Hatchery operations. The discharge temperatures and chemistry of the spring groups suggest a small thermal component which differs among the spring groups (Table 1-3). If this component was reduced or lost it could lower the average temperature of the spring by 2 to 3 degrees Centigrade (Sorey, 1976). The spring temperatures fluctuate naturally. This amount varies for each spring. Figures 1-10 through 1-13 show the average monthly spring temperatures since 1976 as measured by the CDFG. With the exception of the warmer springs, (AB and CD) they show a continuing decline in recent years which begins prior to MP I start up. Yearly temperature fluctuations vary from 4°F (2.2°C) to 0.5°F (0.3°C) depending upon the spring group. In general, the lower temperatures correspond to years with above normal annual precipitation.

Flow rates also vary considerably with seasonal rainfall. Figure 1-14 shows the average monthly spring flow rates for the AB springs. The AB flow rate data collection was initiated in late 1984 and is financed by the Mammoth/Chance geothermal project developer. This spring group shows the influence of a high rainfall year, with flow rate change up to 75%. The only other spring currently monitored for flow rate is spring H-II, III. It shows only 25% change in high rainfall years, such as occured in 1986. This data is to be published shortly by the USGS.

Effluent from the Hot Creek Hatchery (from all four spring groups) contributes a significant portion of the total Hot Creek flow above the gorge during periods of lowest Mammoth Creek flow. Total effluent from the Hatchery springs varies from 17 to 28 cubic-feet/second (cfs) depending upon season (CDFG, 1988).

1.2.2.4 Hot Bubbling Pool

Another surface feature of interest in the area is the Hot Bubbling Pool (HBP), located approximately one-half mile north of the Hot Creek Hatchery (Figure 1-3). This spring-fed pool is of interest because its fluid characteristics are markedly different from the Hatchery Springs, yet it is an equal distance from the Casa Diablo area. The pool is elliptical in shape, measuring roughly 50' x 100'. There is currently no surface discharge from the pool, but the water level and temperature fluctuate regularly at intervals of approximately 7 hours

(Farrar, 1985). The period of these fluctuations is not consistent with earth tides.

The temperature and ionic chemistry of HBP fluid is very similar to that from Casa Diablo area springs (Table 3-1), but simple dilution does not account for different ionic ratios or isotopic concentrations. The Hot Bubbling Pool water level is also believed to display a relationship to local tectonic strain mechanisms and was observed to have drained for a short period after a series of earthquakes in May 1980 (LBL, 1984). The location of the HBP, ajacent to a major fault zone, bears a similar relationship to the structure and occurance of springs at Casa Diablo. Because of the more direct connection to deeper thermal fluid, the HBP could serve as an indicator of changes in subsurface conditions in that area, perhaps registering changes sooner and to a greater degree than would be seen at Hot Creek Gorge springs or the Hatchery springs. No changes in temperature or chemistry of the HBP spring are known to have occurred.

1.2.2.5 Hot Creek Gorge Springs

Several springs discharge at varying rates along Hot Creek Gorge (Figures 1-3 and 1-15). These are associated with a graben structure bounded by two unnamed faults. Temperature measurements have varied from 73° to 94° C (Table 1-3). Total spring flow from this area cannot be measured directly since the major contributing vents are submerged in the creek bed. However, a close estimate of flow rate can be made from chemical flux correlations using the total flow of Hot Creek and its chemical load, measured at the USGS maintained flume (HCF) below the gorge (Farrar, 1985) (Eccles, 1976) (Sorey & Clark, 1981). Such calculations have yielded an average for total Hot Creek spring discharge of 9.5 cfs with a high of 11.6 cfs in 1980, attributed to seismic activity at that time (Farrar, et al 1985). Increases in total flow, apparently due to tectonic strain relationships, appear suddenly and slowly die off returning to normal flow patterns. Recent chemical analyses of the major vents are shown in Table 1-3. They display similar chemical compositions. After allowing for dilution the ionic compositions and ratios are comparable to the Hot Bubbling Pool and Casa Diablo area springs (Figures 1-6 and 1-7). The isotope ratios show significant differences, as described above in the Casa Diablo area discussion and shown in Figure 1-8. No changes in temperature, flow rate or chemistry have been seen in the Hot Creek Gorge springs as a result of MP I power plant operations.

1.3 Subsurface Resources

Subsurface resources in the south and southwest region of the Long Valley caldera include shallow, cold, local groundwaters and deeper thermal fluids. These waters occur at various depths and temperatures. Due to the complex nature of the geologic structure and temperature distribution, the movement of colder groundwater and thermal fluids is not well defined, but the two are believed to interact to some degree. While there is little data on the shallow, cooler water, it is known to occur in alluvial material, which is discontinuous and of varied thickness in the region. More data is available on thermal waters. This data indicates thermal waters circulate in fracture zones allowing mixing to occur with cold groundwater. It may not be possible to characterize these fluids as occuring in distinct vertical zones as might be the case in a layered sedimentary basin.

1.3.1 Shallow, Fresh Groundwater

Shallow, cooler groundwaters are known to occur in the patches of alluvial fill in the area. At least two of these areas located in the Mammoth Basin, are of interest regarding the PLES I Project. The first is a thin, variable layer of alluvial fill at Casa Diablo (0-40 ft thick) which contains cooler groundwater. This water is believed to occur only northwest of the existing MP I power plant and may be connected hydraulically to the shallow basin containing small ponds upslope near U.S. Highway 395. A shallow well in this alluvium is pumped intermittently at a flow rate up to 50 gpm to fill a tank for the existing MP I power plant. It is not used for drinking due to high concentrations of some minerals and possible biological contaminants, but is used to supply water for irrigation and fire protection. A chemical analysis is provided in the PLES I Plans of Operation (PLES, 1986). No analysis of biological contaminants was available.

The alluvial fill becomes much thinner southward of the existing MP I Power Plant and the shallow groundwater may not be continuous in this direction. Shallow groundwater is likely to occur throughout meadow areas near Mammoth/Hot Creek due to its proximity to creek waters. Groundwater may flow near the surface toward the large meadow area east of U.S. Highway 395 extending to Hot Creek Gorge.

Wells located in this meadow indicate a depth of alluvium and lake sediments up to 600 feet (Figure 1-16). These sediments contain groundwater which varies in temperature, but temperature generally increases with depth so that no distinct zones are discernable. Shallow groundwater is likely to be recharged, in part, by water from Mammoth/Hot Creek that runs through the meadow and by meteoric waters flowing in the subsurface from surrounding higher elevations. Possible thermal water interaction is indicated by the elevated temperatures in shallow wells and in the Hatchery springs.

Shallow groundwater from this area probably flows east with the sloping topography. Some of this flow reaches the surface at the Hatchery and between the Hatchery and Hot Creek Gorge which contributes to stream flow. Shallow subsurface flow may then continue toward the Owens River and Crowley Lake.

1.3.2 Subsurface Thermal Resources

Thermal fluids have been located, primarily, in the south and western regions of the Long Valley Caldera. The areas of interest to the PLES I Project are: the Casa Diablo area, the Mammoth/Chance-Fish Hatchery area, and the Hot Creek Gorge area. Well drilling in these areas has identified at least one high temperature fluid zone and has inferred a cooler zone beneath it. Except for well UM-1 at Casa Diablo no other wells drilled in these areas penetrate through the top of the underlying cooler zone to verify the nature of fluids or temperature distributions below.

1.3.2.1 Casa Diablo Area

Well temperature measurements of wells in the Casa Diablo area have identified at least two vertically separate temperature zones. An upper high temperature zone (330-350°F) at 400 to 700 ft. depth, and a lower temperature zone (250-300°F) extending to approximately 2000 feet. A possible third "zone" (300-310°F) is shown in well UM-1 (Figure 1-17). The depth of this zone is approximately 2000 to 2600 feet. Temperatures at depths over 2600 feet tend to be slightly lower and generally isothermal.

As the profiles in Figure 1-17 show, the high temperature zone does not remain at a constant elevation even in the localized Casa Diablo area. The temperature regions do not appear to adhere to distinct stratigraphic boundaries. The upper high temperature zone occurs in various levels of the Early Rhyolite unit and the lower temperature zone extends across the contact between Early Rhyolite and Bishop Tuff. This implies that stratigraphic boundaries may not greatly influence fluid distribution. It is not clear whether the various temperature zones are hydraulically connected. Any such connection involves the fault-fracture network in the area and is complicated by thermodynamic processes.

The likelihood of hydraulic connection between zones and the definition of boundaries is of importance when attempting to model the potential for impacts from the PLES I development on the Hatchery or Hot Creek Gorge springs. Two distinctly different models relating to the source and distribution of thermal fluids beneath the southwestern caldera have developed.

One conceptual model (upwelling/fracture flow model) is based upon the assumption that the source of thermal fluids is thermal upwelling from depth near or in the basement along each prominent fault zone. This would suggest poor lateral hydraulic connection between regions with shallow geothermal fluid. It further implies that there is little potential for direct hydrologic connection between thermal features or reservoirs in the Casa Diablo, Hatchery and Hot Creek Gorge areas.

A second conceptual model (lateral flow model) is based upon the assumption of relatively continuous lateral flow of thermal fluid between the thermally active areas which orginates near the western or southwestern edge of the caldera. This model implies that a direct hydraulic connection exists between the production/injection zones at Casa Diablo and down gradient thermal reservoirs and surface features. Thermal fluids rise from depth in the western caldera and travel horizontally in the shallow (0-2000 ft depth) subsurface. Surface activity and near surface mixing with cooler groundwater occurs in major fault/fracture zones similar to the mechanism described for the previous model.

1.3.2.2 Pressure Data

Whether one or the other proposed conceptual model is correct is of minor importance provided pressure and temperature changes within the hot producing zone, as a result of power plant operations, remains small. If the power plant operation does not significantly change local pressure distributions, then it will not affect the flow or pressure distribution in other areas. Pressure measurement equipment in Casa Diablo wells has recently been upgraded and measurements are now accurate enough for the detection of small scale trends. The improved data quality has confirmed that only small scale effects (1 to 3 psi) take place as a result of present MP-I operations. This response is very low compared to other commercially productive geothermal reservoirs and has led to increased interest in further development (i.e. PLES-I,MP II and III).

The improved data has also allowed more precise calculation of reservoir parameters. This data allowed a value for kh (reservoir permeability-thickness product) to be more confidently chosen for reservoir pressure response calculations presented in Chapters 2 and 3. This value (500,000 md-ft) would generally be considered quite high, but recent test results suggest a kh more than double this value. The value of 500,000 md-ft was chosen to represent the extreme case scenairo. It also takes into account the fact that the calculations in

Chapter 2 represent an area wide approximation. It is likely that an average kh for the region is less than at Casa Diablo since the latter is located directly in a fault zone.

Pump testing of SF35-32 at rates of up to 2100 gpm showed higher productivity with a small pressure drop in SF35-32 and no measurable interference with existing wells (Mesquite, 1986). Chemistry, temperature, and pressure data suggest that both new wells are in communication with the same reservoir as the MP I production wells. However, pressure data from SF65-32 does not indicate direct communication with the injection reservoir since, under simple model assumptions, its pressure should rise 1 to 3 psi due to current MP I injection on the east side of the Casa Diablo area, rather than decrease approximately 1 psi as observed. The pressure in well SF35-32, however, does respond as predicted by the calculations.

1.3.2.3 Temperature Data and Structure

Temperature profiles from selected wells in the area are shown in Figure 1-17. The location of a shallow (400-700 ft deep) high temperature zone in the Casa Diablo area is obvious. A thicker, slightly higher temperature zone can be seen in the Shady Rest well. High temperature zones similar in depth and extent to that found in Casa Diablo wells are seen in the Hatchery and Hot Creek Gorge areas. It is possible that fluid could be flowing laterally from the Casa Diablo area to the Hot Creek Gorge area, cooling along the way. However, a simple lateral flow model does not explain the cooler temperatures in Wells M-1, M-4, and M-5. Subsurface structural complexity, known from drilling in the Mammoth/Chance project area, could help to explain such inconsistencies. For example, Figure 1-16 shows much thicker alluvial fill in the region of the colder, shallow well, M-5.

The upwelling/fracture flow model, describing isolated areas of upwelling thermal fluid associated with fault zones, can be used to explain some inconsistencies such as the Well M-1, M-4, and M-5 temperature data, which are difficult to account for with the lateral flow model.

The theory of lateral flow from the west of Casa Diablo would imply fluids move through or around major faults at Casa Diablo and across fault and stratigraphic boundaries toward Hot

Creek Gorge. Such a path is difficult to envision from the idealized cross-section of Figure 1-16. The extent of fracturing in each of the stratigraphic units would significantly influence fluid flow.

The theory of upwelling in isolated areas does not currently account for hot fluids at Shady Rest, although less is known about the thermal fluid distribution in that immediate area in the absence of temperture data from nearby wells and flow test data. It should be noted that the upwelling/ fracture flow model has associated drawbacks. Past studies and experience show that fault supported reservoirs have limits upon the rate of production and are dependent upon the amount of fluid that is supplied to the fault system from surrounding (hot) rock. The reservoir at Casa Diablo has not yet and may not demonstrate limits if the reservoir is not significantly stressed by the existing or proposed developments. Further drilling and testing will assist in definition of potential limits.

1.3.2.4 Chemistry Data

The chemistry data presented in Table 1-3 indicates a direct relationship between spring and well fluids within the Casa Diablo. This suggests a similar relationship exists at other hydrothermally active areas nearby where little borehole data is available. In particular, the analyses of ionic ratios, and stable isotope groups (regardless of the suggested degree of mixing by cold near-surface groundwater) show close agreement between data from the Casa Diablo producing reservoir and local surface springs. A preliminary analysis of fluid from the Shady Rest well also indicates a composition very similar to that of the Casa Diablo wells, but with a far higher calcium concentration, possibly due to the abundant calcite deposits in fractures observed in the core samples. Differences in fluid chemistry of surface hydrothermal features east of the Casa Diablo and have been explained by a combination of boiling of geothermal fluids and mixing with water of meteoric composition (Sorey, personal communication, 1987). Exceptions do exist, for example the composition of fluid from the Hatchery Area Well CW-2 (Tables 1-3 and 1-4) requires different mixing and boiling percentages to account for its ionic and isotopic composition.

The current status of interpretations of chemical data collected for several years from springs, and more recently from wells, is that the various similarities and differences in the fluid chemistry data base can be used to support both of the proposed conceptual models to some extent. Currently, the chemistry data does not provide indisputable proof for either of the models discussed in this report.

2.0 ENVIRONMENTAL CONSEQUENCES

A description of surface and subsurface hydrologic features which may be affected by operation of the proposed PLES I power plant was given in Section 1.0. The following discussion covers probable consequences with regard to: 1) surface water quality; 2) depletion of shallow, fresh groundwater; and 3) production of geothermal fluid and potential effects on surface springs. To a large extent, potential impacts to springs can only be discussed in a qualitative manner given the current level of understanding of the subsurface hydrothermal system and its relationship to surface thermal features.

2.1 Creeks and Surface Drainage

A potential threat to existing surface water quality downstream of the proposed PLES I site is the accidental discharge of large volumes of geothermal fluid or chemical additives used in well drilling. A lesser threat is posed by natural surface runoff from areas contaminated by spills of fuel or oil from vehicles and machinery and from other chemical compounds used on site for drilling and plant maintenance. There is a low probability of any such contamination occuring if prudent practices are followed. For example, a containment dike is propsed to be built which would prevent any surface runoff outside the plant area and two spill containment structures are proposed outside the plant area which will capture any leakage from piplines or wells. Well blowout and spill contingency procedures are described in the PLES I Emergency Response Plan (see EIS Appendix A). Only a major ground rupture caused by a major earthquake would allow discharge of spilled fluids to local creeks.

In terms of volume released, spills of geothermal fluid resulting from a large pipeline rupture would be the most serious potential event. If a large pipeline carrying the entire plant capacity of geothermal fluid (approximately 5000 gpm at 335°F) ruptured, a loss of several thousand gallons could result even as various pumps are automatically shut off. This includes spillage from pipes located up slope from of the broken line which could drain out. If the breakage occurred on the power plant site, the lost fluid could be contained by a system of dikes and a catchment basin. Outside the plant site the fluid would be contained in the spill containment structures (total design capacity of about 1,700,000 gallons). Approximately 15% would discharge from a broken production pipe as steam, and a further reduction would occur due to evaporation and infiltration into soils. The temperature of fluid from a burst production pipeline would drop to approximately 200°F upon discharge due to a reduction to atmospheric pressure. The discharge temperature of fluid from a burst injection pipline would be approximately 160°F, but none of the fluid would flash to steam. Additional temperature losses would occur as the fluid flows over the ground surface. Temperature effects, though likely to be short term, would be the most significant impact.

The chemical content of the spilled geothermal fluid is essentially the same as that of the nearby hot springs. The chemical content of this fluid would be low in Total Dissolved Solids (1400 ppm) and would not be likely to have a significant impact for a short term event (see chemical analysis of Casa Diablo well fluid, Table 1-3).

It is important to note that approximately 750 gpm of fluid from Casa Diablo wells was intentionally discharged to the creeks for 39 days in 1962 by a former operator. While this caused concern about effects of long term discharge and potential buildup of trace elements in the potable water supply at Crowley Lake, no severe or lasting effects to the creeks or lake were documented (CDWR, 1967, 1973) (Setmire, 1984).

A well blowout, while drilling or due to casing failure, though very unlikely, could result in a loss of 200-700 gpm (after flash) of geothermal fluid at a maximum of 200°C and some drilling fluid. Only production wells drilled in lower elevations at Casa Diablo have shown the characteristic of artesian flow. The duration of geothermal well blowouts would vary considerably, depending upon the circumstances. Such an occurrence would probably have less impact than accidental thermal fluid discharge as mentioned above. The containment structures could hold the spilled fluid while injection of the fluid or control of the well blowout could be completed.

The potential for creek contamination from loss of drilling fluid, such as from a pit or tank failure also has a low probability of occurance. Again, spilled fluid would be captured in the containment structures or pits constructed for drilling purposes. Any residual fluid or solids remaining on the ground surface would be removed during cleanup operations and should not result in environmental damage.

2.2 Shallow Fresh Groundwater

Little is known about shallow groundwater in the south Caldera region. It is generally considered non-thermal, but some mixing with deeper thermal waters probably occurs in areas with surface thermal manifestations (springs, etc.). Shallow fresh water aquifers are belived to occur discontinuously in alluvial material which varies widely in depth over the caldera and the caldera margins.

Environmental impacts resulting from periodic use of the groundwater within the Casa Diablo area are unlikely to occur. A shallow well is currently used to supply the existing MP I plant with water for irritgation, maintenance, sanitation, and fire protection. Some additional amount, similar to current needs, is likely to be required for the proposed PLES I plant. Fresh or reclaimed water will also be necessary for drilling new wells.

A 50 gpm pump relaced the 20 gpm in the groundwater well in 1987 and demonstrated the well is capable of higher flow rates, but continuous pumping of the shallow groundwater could lower the local water table within the Casa Diablo area. An estimate of the likelihood or amount of water level decline cannot be made due to the lack of pump test data for the well. However, no continuous pumping of shallow fresh water is proposed for the PLES I Project. It is unlikely that any significant influence on shallow groundwaters in nearby areas will result since the particular aquifer from which shallow fresh water is produced is probably limited to the Casa Diablo area. No connection is belived to exist between this groundwater aquifer and the more extensive shallow groundwaters in the south caldera area, for example, beneath the meadow along the course of Mammoth Creek toward its confluence with Hot Creek.

2.3 Hydrothermal Resources

Potential impacts of geothermal power production on surface thermal fluid resources (springs and other manifestations) near the Casa Diablo Area are difficult to predict precisely without a more thorough understanding of the geothermal reservoir. Additional drilling testing and analysis of the region would assist in evaluating potential adverse effects on springs. However, standard reservoir engineering calculations can be performed which assist in defining potential limits of what effects may be reasonably considered or have some probability of occuring. Potential effects can only be expected if direct hydraulic connection exists between the geothermal reservoir at Casa Diablo and source of the springs, otherwise no impacts would be likely.

Two distinctly different conceptual models of subsurface thermal fluid origins and flow directions have emerged as discussed in Chapter 1 above. The upwelling/fracture flow model implies that there is no Fish Hatchery and Hot Creek Gorge areas, which in effect precludes the likelihood of potential adverse impacts. The lateral flow model suggests relatively widespread lateral hydraulic communication in the south and southwest caldera region in one or more vertical zones. Such communication between the production/injection reservoir at Casa Diablo and thermal springs at the Fish Hatchery and Hot Creek

Gorge could result in potential adverse impacts to hot springs. However, the principals of groundwater hydrology and reservoir engineering dictate that even large induced changes in the reservoir at Casa Diablo will result is small effects in the reservoir 3-5 miles away, if they are hydraulicly connected. No significant effects have been detected in Casa Diablo reservoir data to date.

2.3.1 Simulated Reservoir Performance Calculations

Since neither reservoir model has been conclusively proven, the lateral flow model has been evaluated below since it allows the greatest probability for potential impacts to surface features. In this way an extreme case scenario can be analysed and the maximum environmental protection will be afforded through applicable mitigation.

Three different methods were used to estimate the effects of producion and injection on the geothermal reservoir under the conservative assumption that hydraulic communicaiton does exist. The first involves a computer program which calculates reservoir pressure responses due to production. It simulates a laterally extensive, homogeneous, isotropic reservoir with no discontinuities or barriers. The second calculation is based on a bulk model and is used to predict the distance that cooler, injected fluid would move outward from the Casa Diablo area and the likelihood of its interference with the various thermal springs. The third calculation involves a heat or energy balance analysis of the region, which predicts the decline in average reservoir temperature due to injection of cooled fluid.

2.3.2 Reservoir Pressure Response Calculation

The computer program used is commercially available (MRMW by BGI) and is currently in use worldwide. It calculates reservoir pressure changes using a linear superposition of the line source solution for radial flow to or from a well that penetrates a homogeneous liquid reservoir or aquifier of constant height. The program can account for the possibility of preferred flow paths along high angle faults and fractures. However, localized hydraulic gradients are not well enough defined in this case, therfore the potential effects of non-uniform flow are not included in the calculations presented below. The model used to represent the region from Casa Diablo to Hot Creek Gorge assumes no hot water recharge. If recharge were included in the pressure response calculation it would significantly reduce fluid pressure declines in the vicinity of production wells. The model also assumes 100% hydraulic communication exists between injection and production zones, even though the actual zones are at different depths. Geologic and temperature logs and recent transient pressure test suggest such complete communication may not occur.

Computer calculations were run for a reservoir permeability thickness product (kh) of 500,000 md-ft. This parameter is the product of average reservoir permeability, and average reservoir height, and is a measure of how much pressure change will occur for known, net flow out of the reservoir. This value is based on recent well test data (not yet published) and previous analysis (Geothermex, 1986). The recent data suggests a far higher kh, therefore the above value may be considered conservative and consistent with other methods used for this study in an attempt to present an extreme case estimate of reservoir impacts. A higher kh would reduce calculated pressure changes (i.e. lower impacts).

The computer model used for the calculations presented below has been successfully applied to predict pressure behavior in other fractured geothermal reservoirs and is used here to provide a quantitative analysis of production and injection at Casa Diablo under the assumptions described above.

First, production from three MP I wells totaling 3800 gpm, at 335°F, with 100% injection in wells UM-1, IW-1, and IW-2 was modeled (Figure 2-1). The second calculation was performed for MP I and PLES-I MP-I plus four other proposed power plants. Operations were assumed to begin in early 1985 for MP I, 1990 for PLES I, MP-II and M/C-I, and 1992 for MP-III. The results of the three cases are presented in Figure 2-1 for comparison, however, cumulative effects are discussed in detail in Chapter 3.

Figure 2-1 shows the calculated reservoir pressure response for Casa Diablo, Fish Hatchery and Hot Creek Gorge areas over forty years. All projects are assumed to be completed after 30 years, but the calculation continues for 10 more years to show the rate of build-up or return to initial pressure conditions.

The results indicate that the 100% injection of produced fluids on the east side of Casa Diablo, as is proposed, prevents pressure in the reservoir from declining at the Fish Hatchery or Hot Creek Gorge areas. Pressure increases are predicted for the east (injection) side of Casa Diablo (not shown in Figure 2-1). Decreases in reservoir pressure are predicted for the west (production) side of Casa Diablo and Shady Rest Well areas. The model indicates most subsurface pressure changes would occur in the first few years of power plant operation followed by a stable or steady state condition. This is due primarily to 100% injection of produced fluid. The results of the calculations are consistent with the low reservoir pressure changes presently observed in existing observation wells (35-32 and 65-32) after approximately 3 1/2 years of operation.

Any combination of effects not accounted for in this model could significantly affect potential reservoir pressure responses. For example, natural subsurface recharge of hot water to the reservoir could reduce the magnitude of calculated pressure changes. Physical boundaries, such as faults or impermeable materials, could increase calculated drawdowns in the Casa Diablo area but at the same time protect areas outside Casa Diablo. However, there is no evidence of pressure boundaries in data to date. Such modeling is normally updated and refined each year on the basis of new and continuing data.

Though the relationship between spring flow rates and reservoir pressure is complex and cannot be modeled precisely, the calculations can be used to establish reasonable limits for potential impacts using extreme case assumptions. The results show relatively low reservoir impacts can be expected, (less than 1 psi at HCG or FH due to MP-I and PLES I) which need not interfere with spring flow rates. These low predicted drawdowns are the result of 100% injection (as proposed). In the absence of 100% injection support, however, a high rate of natural recharge to the system would have similar influence on reducing impacts. One or both effects must be occuring to some degree to allow the extremely low changes in reservoir conditions occuring at Casa Diablo due to MP I operations.

2.3.3 Bulk Model Calculation

A second calculation was performed in an attempt to provide an estimate for the distance that the cooler injected fluid would move from Casa Diablo. The purpose of this calculation is to estimate the potential for interference of cooler injected fluid with the thermal subsurface source supplying fluid to springs. This so-called "bulk model" calculation is based on assumptions of rock thermal properties, porosity, and displacement of fluid outward in an approximately uniform cylindrical front. Average values of rock density, heat capacity and porosity (2600 kg/m , 1000 J/kg C and 5% respectively) were used. An injection fluid temperature of 80 C, injection zone temperature of 150 F and a reservoir thickness of 500 feet were also assumed.

The results, shown in below, include continuous injection of 3800 gpm for MP I and 5000 gpm for PLES I (i.e. total flow = 8,800 gpm). The hydrodynamic front expands outward at a faster rate than the thermal front by the relationship shown below.

$$u_f = \frac{\phi d_f C_f}{\phi d_f C_f + (1-\phi)\ d_r C_r}$$

$$V = r_h^2 h \phi$$

$$r_t = u_t r_h$$

Where:

V = reservoir volume containing injected fluid after 30 years

r_h = radius of hydrodynamic front (ft)

h = reservoir height (assume 500 ft)

ϕ = porosity (assume 5%)

r_t = radius of thermal front (ft)

u_t = thermal mass

d_f = fluid density (950 kg/m)

C_f = fluid heat capacity (1000 cal/kg- C)

d_r = rock density (2600 kg/m)

C_r = rock heat capacity (240 cal/kg- C)

The calculated position of the thermal front indicates that the distance cooled fluid moves away from the Project site, for both PLES-I and MP-I operating is shown below:

Distance of Thermal Front From Project Area

After 10 yrs	20 yrs	30 yrs
730'	1130'	1260'

This calculation is simplistic, but useful for comparison with other models. It is possible that fractured rock could allow preferred flow paths to carry injected fluid beyond the calculated fronts. However, results indicate that a very large distortion (approximately equal to twelve times the calculated distance) of the calculated front would be required for the lower temperature fluid to travel as far as the Fish Hatchery (approximately 3 miles distant) or Hot Creek Gorge areas (about 5 miles distant). This thermal front would first be observed in monitoring wells before reaching the Hatchery or Hot Creek Gorge areas. It is also significant that gravity segregation is not accounted for in this calculation. This effect allows colder fluid to sink deeper into the reservoir, decreasing the probability of near surface impacts. Gravity segregation models have been used to study other reservoirs and could be used

·hereas new data on this reservoir is obtained. At present, gravity segregation modeling would not be meaningful until subsurface fluid movement is better defined.

The assumed porosity of 5% may be low based on recent estimates of porosity within Casa Diablo area. In this calculation, the higher the porosity, the smaller the computed distance of thermal front propogation. Thus, using 5% is in keeping with the extreme case scenario presented here. Also, the reservoir thickness of 500 feet may be low based on lithologic and temperature data. It is possible that the effective injection zone thickness is greater than the 500 feet assumed for this calculation. This would decrease the calculated distance of the hydrodynamic and thermal fronts, reducing the potential for impacts on springs. These two parameters, porosity and reservoir thickness, have compensating effects in the calculations. Using slightly different values for each would not alter the results significantly.

A separate calculation, related to distortion of the bulk model thermal front, was performed. It is based only on the subsurface hydraulic gradient which may induce lateral west to east flow. The effect of this gradient would be to allow a buldge or distortion of the injected fluid down-gradient to the east which is not accounted for in the bulk model.

As previously mentioned, there is some debate among experts as to whether such a lateral west-to-east flow exists. Assuming it does exist for the purpose of estimating an extreme case scenario, a rough estimate of its effect can be calculated from the regional groundwater/geothermal gradient. A fluid velocity of 0.06 ft/day was calculated based on a horizontal permeability corresponding to kh= 500,000 md-ft. (used in the computer model) and a value for the local groundwater gradient of 0.0135 ft./ft. (estimated from the water level contour map of Farrar, et al, 1985).

The results indicate that fluid moving from Casa Diablo would take about 100 years to reach the Hatchery, and 150 years to reach Hot Creek Gorge, areas. Therefore, any potential changes would migrate excecedingly slowing and would provide ample time for implementation of mitigation measures to reduce or eliminate the potential for impacts to the Hatchery or Hot Creek Gorge areas.

These results are based on the assumption that lateral west-to-east subsurface flow occurs in the region and no provision is made for the effect of preferred flow paths, which are often associated with fractured reservoirs. Calculations of the movement of fluid in the subsurface induced by the local groundwater gradient does not take into account reheating of injected fluid through contact with hot reservoir rock which could significantly slow or reduce impacts naturally.

The estimated position of the thermal front, including some distortion by lateral flow, indicates breakthrough of cool injection fluid is not likely to be a potential threat to existing springs.

2.3.4 Heat (Energy) Balance Calculation

A third method of predicting the effects of geothermal production and injection within Casa Diablo area is by the heat or energy balance technique. This method is used here to estimate the geothermal reservoir temperature declines which may be anticipated due to heat withdrawal. Usually this method is used as a research tool to establish the evolution of natural heat inflow and outflow from an undisturbed hydrothermal reservoir. It has not proven effective for calculation of effects on commercially productive reservoirs, because the amount and the effect of recharge to the reservoir are usually underestimated. The recharge rate cannot be easily measured since it does not necessarily discharge at the surface. Recharge, if measured by surface discharge, is usually found to be minor in comparison to subsurface recharge actually available to support commercial production. Currently productive commercial geothermal reservoirs in the Western United States demonstrate far greater recharge than is measured by surface discharge. However, overproduction and large pressure drawdowns can and do occur as a result of geothermal production without appropriate reservoir management.

This method is presented for completeness in analysis methods and because a previous EIR (Westec, 1987) and a recent study (Papadopulos, 1988) have used this technique. A worst case scenario is presented based upon collectively conservative assumptions of high porosity (15%), heat in place (10 x 10^17 calories), low recharge (equal to surface discharge, assume 130 kg/s) (Sorey and Lewis, 1976, use 250 kg/s) and 100% power plant capacity factor.

The equations used are based upon Papadopulos 1988 report and are summarized below.

$$I - O = dS/dt$$

Where:

I = rate of heat inflow (recharge + injection, cal/sec)

O = rate of heat inflow (spring flow + production, cal/sec)

d/S = change of heat stored over time

$$S = V \quad C_fd_f + (1-\phi)\ C_rd_r\ T$$

Where:

S = quantity of heat stored

V = reservoir colume (11×10^9 m^3)

C_f = heat capacity of fluid (1000 cal/kg-C)

T = average reservoir block temperature
(i.e. 1 = 180°C, 2 = 150°C, 3 = 130°C, 4 = 100°C)

d_f = density of fluid (950 kg/m)

d_r = denisty of rock (2600 kg/m)

ϕ = rock porosity (assume 15%)

Natural Recharge + Total Injection - Natural Outflow + Total Production = Change in Stored Heat with Time

$$Q_{re}C_fd_fT_{re} + Q_id_fC_fT_i - Q_oC_fd_fT_o + Q_pC_fd_fT_p = V\left[\phi C_fd_f + (1-\phi)\ C_rd_r\right] dT/dt$$

Where:

Qre = Recharge flow rate (m^3/s)

Qi = Injection well flow rates (m^3/s)

Qo = Natural surface outflow (m^3/s)

Qp = Production well flow rates (m^3/s)

Tre = Temperature of Recharge water (assume 200°C)

Ti = Temperature of injected fluid
(assume 80°C at Casa Diablo and 60°C at Mammoth/Chance)

To = Temperature of natural outflow (Block temp.)

T_p = Temperature of produced fluid

Note: Natural Outflow term should include surface conductive heat loss (cal/sec) if significant.

The equation is solved for the temperature of each block for any period of a geothermal project life. It can also be extended after project completion to predict natural temperature buildup caused by continued recharge flow. For this calculation, all power plants are assumed to start up and shut down simultaneously. Also, a 100% plant capacity factor (i.e. no breakdowns or maintenance stoppages occur) is assumed.

The reservoir volume assumed by Papadopulos is 3.55x10^9 m , using a thickness of 300 m. This volume is too small to allow even a conservative reservoir heat value of 10 x 10^17 calories to be considered and does not include the Hot Creek Gorge springs area. A larger area is used for this calculation (see Figure 2.2) with the same reservoir thickness (300m). It includes areas for which there is well temperature data available (i.e. from the Shady Rest Well area to Well CH-10 near Hot Creek Gorge). Initial reservoir block temperatures are also based on observed well data. It should be noted that it is not possible for the reservoir (or block) temperature to be reduced below the fluid injection temperature by this method. The injection temperatures used here are 80° C for Casa Diablo projects and 60°C for the Mammoth Chance projects. The division of the reservoir into blocks is shown in Figure 2-2. Boundary conditions and reservoir parameters are listed in Table 2-1.

Though this calculation does not predict a 30°C decline at Casa Diablo, commercial production would cease long before the reservoir temperature changed by this amount. This is due to power plant design constraints. Further, no financial institution or investor would invest in such a project if there were any reasonable likelihood of such declines occuring within the projected power plant life. Though some poorly planned geothermal projects have been cut back due to faulty analysis of intitial conditions none are known to have been reduced by temperature declines in the reservoir.

The results for only one power plant operating (MP-I) are given below.

MP-I ONLY

Predicted Reservoir Temperature Change (°C)

Area	After 10 yrs	20 yrs	30 yrs
Casa Diablo	- 1.8	-4.0	-6.1
Fish Hatchery	0	0	0
Hot Creek Gorge	0	0	0

MP-I and PLES-I

Predicted Reservoir Temperature Change (°C)

Area	After 10 yrs	20 yrs	30 yrs
Casa Diablo	-5.6	-10.7	-15.4
Fish Hatchery	0	0	0
Hot Creek Gorge	0	0	0

The results, shown graphically in Figure 2-3, indicate a temperature decline in the Casa Diablo area (Block 1) and no declines in the Fish Hatchery and Hot Creek Gorge areas due to the warmer recharge water (130 kg/s) moving laterally from west to east. If the recharge volume available is greater than existing surface discharge, as assumed, smaller declines will be predicted. However, it should be noted that the size of Block 1 allows flow to be induced from the entire volume toward the producing wells which is, in effect, a form of recharge. A similar model could be set up which allows a smaller reservoir volume from which producing wells can draw fluid but with greater recharge. Exisiting data from wells at Casa Diablo could support either approach and the "downstream" effects in the reservoir toward the Hatchery and Hot Creek Gorge areas would be the same as shown above.

The results for the Hatchery and Hot Creek Gorge areas show no change in temperature since no production, other than spring discharge occurs in these areas. The temperature of Blocks 2,3 and 4 are maintained by the continued recharge from Block 1 which remains a higher temperature than the others. This higher temperature recharge would cause a minor natural increase in temperature (<5°C) of those blocks were it not for surface conduction and spring discharge.

In summary, it is difficult to precisely predict the effects on surface thermal features resulting from production/injection operations at the proposed PLES I Project and the existing MP I Project. The simple model calculations described here indicate that, even assuming hydraulic communication exists, the potential for subsurface impacts to extend 3 to 5 miles to the Hot Creek Hatchery and Hot Creek Gorge areas is very low. It is possible that direct hydraulic communicaion does not exist in which case no impacts are likely to extend to areas beyond the graben in which the Casa Diablo area is located.

Subsurface effects can not be related directly to thermal springs. Special circumstances exist at each area, such as those at the Hatchery springs, where it is estimated that 2-3% of the average flow is thermal water. The temperature of the thermal fluid component of these springs is unknown. It has been estimated that a loss of the entire thermal component could result in a lowering of average spring temperature of 2° to 3° degrees Centigrade (Sorey, 1976). On this basis a 30°C geothermal reservoir temperature decline in the Hatchery area would be required before a 1 C change could be expected in the average Hatchery springs temperature (Sorey, 1988). This 30°C/ 1°C relationship cannot be considered a certainty, however. Only continued monitoring of springs and wells may allow cause and effect relationships to be established.

2.3.5 Monitoring Programs

Since a precise analysis of hydrologic effects due to increased geothermal development at Casa Diablo is not possible on the basis of current data, a closely controlled program of surface and subsurface fluid monitoring should be established. This program should include measurement of chemistry, flowrate and temperature of important surface features; temperature, pressure and chemistry of one or more observation wells; injection well pressure; temperature and rate and production well temperature, pressure, flowrate and chemistry. Continuous monitoring and periodic sampling of various features is already underway by the USGS and others (Farrar, et al, 1985, 1986).

A monitoring program has been prepared by PLES (Plan of Baseline Data Collection, PLES I - 10 MWe Binary Power Plant Project, 1987), and is also underway.

The PLES proposal includes a significant upgrade in the accuracy of downhole pressure measurement during testing and production of wells, which allows more accurate estimates of reservoir parameters than was previously available. This, along with other proposed monitoring, drilling and well testing should allow the construction of more detailed models than the simplified versions used for calculations presented above. Calculations may then be updated and improved, and potential adverse impacts to the reservoir and/or springs can be evaluated periodically. Any monitoring plan should allow some degree of flexibility. Future data may show a lack of response or reduced need to monitor one feature, while increased attention should be directed to another area. Any monitoring guidelines would have to be agreed to in advance by both the regulating body and the project operator.

It was previously recommended that a monitoring well be drilled at an accessible and permissable location chosen by an appropriate agency. Such a well (SF65-32) was drilled to a depth of 250 feet and pressure data has shown it to be in communication with the geothermal production zone of the proposed project. The primary function of the monitoring well is to serve as an early warning of potential changes in reservoir pressure or temperature which may propagate toward the east or southeast and which could potentially affect springs.

At present, the Casa Diablo area production zone pressure does not appear to respond directly to injection, since the pressure response calculations used above would predict an increase in pressure for the SF65-32 location. However, the actual measured pressure in Well SF65-32 showed a slight decrease in response to production of (approximately 1 psi) when MP-I wells were restarted after a brief shut-in. This is not surprising given the complex structure in the Casa Diablo area.

On a regional scale however, the pressure response calculations has been proven effective for analysis of pervasively fractured reservoirs and should effectively model pressure changes due to production and injection in the Casa Diablo area.

Background data collection should be continued to allow baseline values to be established and action levels (re: temperature, pressure and chemical constituents) to be agreed upon by appropriate government agencies. The data collected by the USGS and others thus far, presented by Farrar, et al (1985, 1986), should allow general guidelines to be established which could then be updated as new data is added. Additional data would be helpful in delineating more precisely to what extent pressure, temperature, chemical and flowrate changes can be attributed to natural causes (e.g. tectonic strain and seasonal precipitation amounts) and what changes, if any, may be attributed to PLES I power plant operations.

3.0 CUMULATIVE IMPACTS

Several other developments requiring geothermal fluid are proposed for the south caldera region in addition to the existing MP I and planned PLES I power plants. These include: 1) MP II and MP III, 10 MW power plants within the Casa Diablo area; 2) Mammoth/Chance I, 10 MW power plant, northwest of Hot Creek Hatchery. Proposed fresh water users include: 1) Mammoth Lakes Airport development (also referred to as the Doe Ridge project), near the airport southeast of Hot Creek Hatchery, 2) the Chance Ranch located near the Sheriff's substation and (3) the Town of Mammoth Lakes.

3.1 Surface Resources

The primary threat to surface freshwater resources is from potential spills of geothermal fluid, petroleum products and other chemical compounds which may be used on-site for construction, maintenance and drilling. The probability of contamination from spills or natural runoff from contaminated soils increases with each additional power plant installed or under construction but remains low. However, the chance of having an event such as a spill or well blowout occuring at more than one power plant at any given time is remote. Hence the effect of a single event would be similar to that described in Section 2.1.1.

3.2 Shallow Fresh Groundwater

The existing shallow groundwater well within the Casa Diablo area should be sufficient to supply the needs (primarily landscaping and fire protection) of the existing MP I plant and contribute to the needs of the proposed PLES I plant. No definite limits are known for the shallow fresh water aquifer at Casa Diablo and demand requirements have not been well defined for the proposed MP II and MP III or PLES I developments. Assuming the one existing and the three proposed power plants at Casa Diablo would each need approximately the same quantity of fresh water, four times as much as is currently produced would be required. No other users of this supply are known or anticipated. Increased production, possibly including a new well, could lower the fresh water table locally.

Other projects which pump fresh water may impact shallow groundwater resources but no significant cumulative impact is likely to result from the low level usage planned for projects in the Casa Diablo area. As mentioned in Chapters 1 and 2, the non-potable shallow groundwater at Casa Diablo is associated with shallow alluvial material that appears to thin out southeast of the area, and neither the alluvium nor a significant shallow fresh water resource is believed to be continuous down gradient toward the Chance Ranch, Mammoth/Chance or Doe Ridge projects or directly connected to aquifers in the Mammoth Lakes Areas. A greater thickness of alluvium, along with a larger freshwater aquifer, is believed to occur in those areas. Little effect on other aquifers can be anticipated from cold groundwater production within the Casa Diablo area

It is suggested that an entire study be dedicated to defining groundwater aquifers in the Mammoth Creek drainage basin for the purpose of evaluating cumulative impacts. The size, number and extent of aquifers and sub-basins in this area is poorly understood. The shallow cold groundwater supply in the Casa Diablo area is belived to be minor. Even with all proposed projects at Casa Diablo in place, shallow fresh groundwater use and impact on a regional scale is likely to be insignificant. However, much larger fresh groundwater uses are proposed outside the Casa Diablo area which may significantly affect groundwater resources on a regional scale. Any such study would require more data from groundwater aquifier testing, estimates of the depth of alluvium and basalt layers in the area and more precise definition of well locations and flow rates required for each project.

3.3 Hydrothermal Resources

The MP II and MP III Projects will be binary power plants, each with similar production/injection requirements to PLES I (i.e. approximately 5000 gpm each). For the purpose of this study, production is assumed to be from the same reservoir as MP I and PLES I. Pressure response calculations were performed under the same assumptions and for the same purpose as discussed in Chapter 2. The analysis method shows the potential effect of all proposed power plants on the geothermal reservoir. The results are given as predicted pressure changes in the subsurface reservoir at depth, in the area of the springs (see Figure 2-1).

Area	Predicted Reservoir Pressure Change (psi) After 10 years	20 yrs	30 yrs
Casa Diablo	+5.53	+5.53	+5.53
Fish Hatchery	-1.88	-1.88	-1.88
Hot Creek Gorge	+.38	+.38	+.38

Includes MP-I, PLES-I, MP-II & III and M/C-I.

The results demonstrate that for a kh=500,00 md-ft the responses stabilize two years after the proposed power plants begin operating. This steady state occurs before the first 10 year interval listed above (see Figure 2-1 for effects before 10 years). The last project to start up is assumed to be MP III in 1992. The flat response is primarily due to 100% injection, which is proposed for all the projects. The final well locations are not yet known for the Mammoth Chance I project (M/C-I). The well locations assumed for this calculation are those shown in the Revised Mammoth Chance I EA (1987).

As expected, the pressure changes are greater than for the MP I and PLES I power plants operating together (see Chapter 2). At Casa Diablo, pressure declines are expected on the west side in the vicinity of the producing wells. Increases are expected on the eastern side. The pressure changes predicted are more than twice that calculated for MP I and PLES I only. However, these values are extremely low compared to what would be considered significant for exisiting geothermal projects in other areas.

The results for the Fish Hatchery area have reversed from the previous case (MP I and PLES I only). It no longer indicates a small pressure increase. Rather, a decrease is predicted, due to pumping at proposed well locations for Mammoth Chance I. The decline is low, equivalent to less than five feet of water head in a static well.

The calculated increase at Hot Creek Gorge is essentially insignificant and may be unmeasurable given the observed magnitude of background effects in pressure data taken from local wells (eg. CH-10).

Bulk Model Calculation

The results of the bulk model calculation, by the same method described in Section 2.3.3, for all five proposed power plants (MP I, PLES I, MP II & III, and M/CI) are shown below.

Distance of Thermal Front from Project Area

Casa Diablo			Mammoth/Chance		
After 10 yrs	20 vs	30yrs	After 10 yrs	20 yrs	30 yrs
980 ft	1390 ft	1700 ft	850 ft	1200 ft	1470 ft

The maximum calculated distance traveled from the project area is less than one third of a mile, which is not significant compared to the distance to the Fish Hatchery (3 miles) and Hot Creek Gorge (5 miles). The Mammoth Chance project thermal front is calculated to travel approximately 0.28 miles. The distance from the proposed Mammoth Chance injection wells to the Fish Hatchery and Hot Creek Gorge is approximately 1 mile and 3 miles respectively. Overall, by this method of calculation, the potential threat to springs is remote.

Heat Balance Calculation

The results of the heat balance calculation for the five power plants (MP I, MP II, MP III, PLES I and M/C I) is given below.

Predicted Temperature Change (°C)

	After 10 yrs	20 yrs	30 yrs
Casa Diablo	-11.4 C	-21.1 C	-29.4 C
Fish Hatchery	-7.6	-14.2	-19.8
Hot Creek Gorge	0	0	0

The same properties and parameters apply from Section 2.3.4 and are listed in Table 3.1. The only changes are to flowrates, allowing an additional 5000 gpm in Block 2 (Figure 2-2) for each MP II & III power plant and 10,000 gpm in Block 4 for the M/C I plant.

The results indicate a moderate temperature decline for the Fish Hatchery area (Block 3). This decline could potentially result in a 1 C reduction in spring temperature using rationale based on approximately 3% of spring flow having thermal origin (Sorey 1976, 1988).

In summary, the effect of the proposed PLES I geothermal power plant, on the thydrothermal resources, together with other proposed geothermal projects, is the major issue of concern. Calculations performed in an attempt to predict these effects were based on simple models using available data and are believed to simulate what effects would occur in the reservoir under extremely conservative circumstances. The calculations showed that no significant reduction in subsurface reservoir pressure near thermal springs in the Hatchery and Hot Creek Gorge areas is likely. Nor are reservoir temperature declines predicted to significantly effect springs. However, significant reservoir changes are predicted for the vicinity in which the proposed power plants are to operate. These changes may only be anticipated in the absence of significant subsurface recharge to the shallow (500-1000 ft deep) geothermal reservoir. Given the reservoir performance at the existing MP-I plant and the other data reviewed in this report, there is ample evidence to suggest that the volume of recharge available is greater than that which can be measured as discharge at the surface. The effect of such recharge would be to decrease changes predicted/by the above calculations and possibly eliminate any potential threat to the springs at the Fish Hatchery or Hot Creek Gorge.

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Table 1-1

Creek Flowrates (cfs)

Location		Low	High	Average
Ephemeral tributary to Mammoth Creek at Casa Diablo (1)		0	40	N/A
Mammoth Creek Flume (MCF)(2)				
	June	14	191	82
	Sept	1.5	33	8
Hot Creek Flume (HCF)(2)				
	June	33	265	115
	Sept	26	86	41

(1) - from PLES I Plans of Operation (PLES, 1986)

(2) - Calculated from monthly flow totals 1932-1971
CDWR, 1973

Table 1-2

Summary of Selected Creek Flow Data

Mammoth/Hot Creeks, Mono Co., California

Location	Date	Flowrate (cfs)	Temp. °C	Specific Conductance u /mho per cm
1) MC 395	7/20/86	60.4	14.3	49.4
2) Mammoth Creek Flume (MCF)	9/25/81	-	10.4	135
	5/24/82	102	5.5	57
	7/20/86	62.8	14.4	65.4
3) Hot Creek above Hatchery	9/25/81	-	15.4	252
	5/24/82	96.1	18.0	106
	7/20/86	58.4	-	117
4) Hot Creek Flume (HCF)	9/25/81	-	30.8	470
	5/24/82	206	17.0	236
	7/20/86	109.5	25.1	307

From Setmire, 1984 and
C. Farrar, personal communication 1987.

Table 1-3 Chemical analyses of waters from selected springs and wells in the Long Valley area, Mono County, California
(revised from Farrar, et al, 1985 & 1986) (Units are milligrams per litre)

Feature	Collection date	Temperature (°C)	pH	Ca	Mg	Na	K	ALK	SO_4	Cl	F	SiO_2	Dissolved Solids	As	B	Li	Hg
Casa Diablo area - springs in sections 15, 31, 32, 33, t.3S., R.28E.																	
Geyser (CDG)	11/19/83	92.0	9.4	1.5	0.53	389	40	469	152	269	10.1	341	1,212	2.5	12.7	3.7	-
	05/09/84	90.1	8.2	0.8	0.1	410	38	382	160	300	12.0	268	1,480	1.8	12	3.2	1.2
	09/04/84	90.8	8.2	1.3	<0.1	410	40	388	160	310	13.0	-	1,470	1.8	13.0	3.0	0.1
	05/28/85	92	9.1	2.2	0.06	458	44	395	137	298	13.7	300	1,326	1.9	13.5	3.8	<50
North Spring (CDNS)	03/15/83	88.5	6.7	-	-	-	-	-	-	270	9.8	-	-	2.0	13.0	-	-
	06/03/83	92.5	6.8	8.7	1.2	235	24	-	155	260	10.0	216	-	-	13.0	1.2	-
	08/18/83	91.5	6.7	-	-	-	-	-	160	260	9.6	130	-	2.1	12.0	-	-
	10/04/83	91.5	6.8	9.1	1.2	240	23	47	160	260	9.3	220	971	1.9	12.0	1.1	0.3
	12/15/83	89.5	7.1	10.0	1.5	240	22	45	170	270	12.0	210	1,010	1.6	12.0	1.1	-
	05/09/84	89.5	6.9	10.0	1.4	250	25	61	190	270	9.1	200	1,020	1.5	11.0	1.3	0.5
	09/04/84	92.8	7.2	10.0	1.4	240	26	58	160	280	9.2	220	1,010	1.5	-	1.2	0.5
	11/11/84	89.8	6.8	10.0	1.3	240	24	36	170	270	8.0	220	1,000	1.2	13.0	1.2	0.3
	02/06/85	86.1	6.3	11.0	1.4	230	21	43	180	260	8.9	260	1,020	1.9	11.0	1.0	0.2
	07/16/85	90.0	6.7	12.0	1.5	250	23	39	170	270	10.0	220	1,010	1.5	11.0	1.2	1.2
South Spring (CDSS)	08/27/82	93.0	8.4	11.0	2.2	290	27	186	150	260	8.1	210	1,090	1.5	11.0	-	-
	11/17/82	93.5	7.8	9.9	2.2	280	27	175	160	250	8.8	200	1,080	1.6	11.0	-	-
	01/14/83	86.0	-	-	-	-	-	-	-	250	-	-	-	1.5	-	1.7	0.2
	02/04/83	81.0	-	-	-	-	-	-	-	240	11.0	-	-	1.4	11.0	1.7	0.3
	03/15/83	80.0	6.6	-	-	-	-	-	-	240	8.5	-	-	1.5	11.0	1.8	0.1
	05/03/83	80.5	6.5	-	-	-	-	-	-	230	6.9	-	-	1.6	-	-	-
	06/03/83	84.0	6.7	23	3.3	320	31	281	225	205	8.2	200	-	-	9.6	1.8	-
Casa Diablo area - wells in sections 32, 33, T.3S., R.28E.																	
Endogenous (END-5)	05/19/72	94.0	9.2	0.9	0.1	390	45	368	130	280	12.0	340	1,217	2.2	14	2.8	-
IW-2	01/04/83	-	9.7	3.5	.008	401	10	464	118	132	23.7	91	1,072	0.18	10.8	0.22	-
MBP-1	01/04/83	-	8.8	5.1	0.04	431	47	405	132	300	12.1	63	1,248	0.21	10.6	3.48	-
	07/11/85	168	6.2	3.9	0.10	260	33	355	110	260	11.0	250	1,270	1.0	11.0	2.7	2.6
MBP-3	07/12/85	171	6.1	1.2	0.10	350	36	345	120	270	11.0	250	1,250	1.1	11.0	2.6	2.3
MBP-2	01/04/83	-	9.1	1.8	0.03	430	45	410	133	288	12.8	65	1,236	0.23	10.8	3.52	-
MBP-4	01/04/83	-	8.8	1.4	0.02	453	52	425	135	300	13.6	188	1,414	0.24	11.7	3.98	-
	10/13/85	173	6.0	1.8	0.10	340	35	360	110	270	10.5	240	1,270	1.2	11.0	2.6	1.9
MBP-5	01/04/83	-	9.2	2.6	0.02	435	34	389	172	267	14.7	75	1,248	0.20	10.3	3.98	-
	10/13/85	168	6.3	6.0	0.10	340	31	360	110	270	10.5	240	1,270	0.7	11.0	2.7	1.8

Table 1-3. Chemical analyses of waters from selected springs and wells in the Long Valley area, Mono County, California (continued-pg.2)
(revised from Farrar, et al, 1985 & 1986) (Units are milligrams per litre)

Feature	Collection date	Temperature (°C)	pH	Ca	Mg	Na	K	ALK	SO_4	Cl	F	SiO_2	Dissolved Solids	As	B	Li	Hg
Casa Diablo area - wells in sections 32, 33, T.3S., R.28E. (continued)																	
Union (M-1)	01/04/83	-	9.4	0.9	0.02	422	18	415	172	180	14.5	61	1,126	0.14	7.57	0.82	-
Colton Spring (CS)	08/26/82	93.0	9.1	1.4	0.20	390	25	354	140	270	12.0	240	1,310	1.6	12.	-	-
	12/04/82	95.0	8.4	1.2	0.07	370	25	367	140	250	11.0	240	1,290	1.5	12.	-	-
	01/14/83	93.0	-	-	-	-	-	-	-	260	-	-	-	1.7	-	2.9	0.1
	03/15/83	91.5	8.3	-	-	-	-	-	-	260	12.0	-	-	1.7	12.	2.9	0.2
	05/01/83	91.5	8.4	-	-	-	-	-	-	260	12.0	-	-	1.5	12.	-	-
	06/03/83	93.0	8.3	1.2	0.01	385	25	370	135	250	10.0	240	-	-	11.	2.8	-
	08/14/83	92.0	8.4	1.3	0.3	380	28	355	130	260	12.0	-	-	1.4	11.	-	<0.1
	10/06/83	91.5	8.3	1.3	-	370	24	355	140	260	11.0	240	1,280	1.6	11.	2.8	0.1
	12/15/83	89.1	8.4	1.7	<0.01	370	23	359	140	270	12.0	-	1,280	1.5	11.	2.9	0.5
	04/25/84	70.0	8.4	1.4	0.02	384	32	390	129	258	9.6	315	1,376	1.4	11.4	2.9	-
	05/09/84	91.4	8.3	1.3	<0.01	370	28	353	150	270	12.0	230	1,340	1.3	11.	3.3	0.3
	02/04/85	93.1	8.3	1.4	<0.01	360	26	335	130	270	11.0	300	1,320	1.7	11.	2.5	0.3
	05/26/85	93.8	8.7	2.0	0.05	408	27	365	133	260	10.7	250	1,266	1.5	11.6	3.5	<50
	12/18/85	92.9	8.5	1.4	<0.01	380	27	393	140	270	13.0	250	1,310	1.7	12.0	3.0	0.3
Meadow Spring (MS)	08/27/82	60.0	7.5	3.8	0.8	230	37	132	110	210	8.7	210	910	2.2	9.1	-	-
	12/05/82	61.0	5.9	3.5	0.6	220	39	134	120	200	8.0	200	894	2.2	9.4	-	-
	03/15/83	61.0	6.2	-	-	-	-	-	-	200	8.8	-	-	2.4	9.0	0.16	0.1
	05/01/83	61.0	6.6	-	-	-	-	-	-	180	8.3	-	-	2.0	8.1	-	-
	06/03/83	63.0	6.9	3.1	0.46	200	31	127	100	170	7.8	-	-	2.0	7.5	1.4	0.1
	08/14/83	62.3	6.4	3.2	0.53	200	39	135	100	180	7.6	180	-	2.1	7.8	1.4	0.9
	10/06/83	64.4	6.2	4.1	0.57	210	36	122	120	190	7.2	190	844	2.0	8.5	1.3	0.1
	12/15/83	56.0	6.2	4.4	0.60	200	32	119	120	190	7.5	180	824	1.8	8.0	1.4	0.2
	04/05/84	60.0	6.2	3.5	0.60	200	39	109	120	200	7.5	190	881	2.0	8.5	1.4	0.3
	05/10/84	63.3	6.3	3.4	0.60	210	39	115	120	200	7.7	190	865	1.8	8.6	1.5	0.3
	10/11/84	64.0	6.7	4.6	0.13	220	43	115	134	199	6.8	235	855	2.2	9.1	1.6	-
	05/26/85	62.5	6.2	4.2	0.65	241	36	106.	122	212	7.9	189	768	2.1	9.3	1.6	<50
SS-2	11/17/84	12.0	6.8	22.0	6.4	23	5.1	130	10	7.4	-	60	-	0.13	0.4	0.1	-
	07/16/85	20	6.9	13.0	5.8	32	5.3	91	11	15	0.4	53	182	0.05	0.4	0.1	0.2
Fish Hatchery area - springs in sections 34, 35, T.3S., R.28E.																	
AB Supply	07/26/73	14.5	7.3	10.0	8.4	21	4.8	91	12	6.5	0.3	56	175	0.05	0.3	-	-
	05/25/82	14.5	6.8	10.0	10.0	30	-	-	-	-	-	50	-	-	0.3	.07	-
	06/21/84	16.0	7.1	13.0	9.7	24	5.1	111	10	8.0	0.4	57	187	0.02	.37	.08	0.1
	04/12/85	15.5	6.5	-	11.	25	-	80	10	10.	-	50	125	0.02	0.4	-	1
	04/28/85	15.9	7.0	-	11.	27	5.9	110	13	11.	0.2	61	197	0.04	0.4	.94	<0.1
	05/30/85	15.7	6.7	12.4	8.4	23	5.2	96	10.5	12.1	0.3	56	190	<0.1	0.5	.07	<50
	10/31/85	16.8	7.2	-	9.	26	-	110	9	11.	-	50	180	<0.01	0.2	-	<2

Table 1-3. Chemical analyses of waters from selected springs and wells in the Long Valley area, Mono County, California (continued-pg.3)
(revised from Farrar, et al, 1985 & 1986) (Units are milligrams per litre)

Feature	Collection date	Temperature (°C)	pH	Ca	Mg	Na	K	ALK	SO_4	Cl	F	SiO_2	Dissolved Solids	As	B	Li	Hg
Fish Hatchery area - springs in sections 34, 35, T.3S., R.28E. (continued)																	
CD Supply	06/14/66	16.0	7.2	9	7	22	5	88.5	7	5	0.3	-	150	0.05	.17	-	-
	05/25/82	14.8	6.8	10	10	30	-	-	-	-	-	50	-	-	.3	.07	-
	06/21/84	14.0	7.1	11	8.1	20	4.2	97	9.7	3.7	0.4	53	155	0.03	.19	.06	0.1
	04/12/85	14.0	6.6	-	8	20	-	95	9	3	-	47	145	0.02	.2	-	1
	04/28/85	14.4	7.1	12	8.8	21	4.6	89	11	3.9	0.3	57	167	0.04	.2	.06	-
	10/31/85	14.1	7.0	-	8	21	-	95	8	4	-	47	170	0.01	.3	-	<2
H-I	06/14/66	12.0	7.5	11	6	19	5	83	7	4	0.3	-	135	0.03	.13	-	-
	05/25/82	13.0	6.8	10	7	10	-	-	-	-	-	50	-	-	.10	.05	-
	06/21/84	12.8	7.2	11	6.9	17	3.7	88	9.3	2.1	0.3	50	136	0.02	.13	.05	0.1
	04/28/85	12.9	7.2	11	6.8	18	4.0	81	11	2.1	0.3	51	143	0.04	.12	.05	
H-II, III	06/14/66	12.0	7.3	12	5	16	4	75	8	3	0.3	-	120	0.02	.08	-	-
	05/25/82	11.0	7.1	10	5	10	5	-	-	-	-	-	-	-	.1	.05	
	11/16/83	11.0	7.2	12.7	5.1	12	3.2	71	-	-	-	34	-	-	-	.04	-
	06/21/84	11.1	7.3	13.0	4.7	12	2.9	70	11	1.5	0.2	39	104	0.02	.09	.04	<0.1
	04/28/85	10.8	7.3	14	4.7	12	3.2	64	10	1.7	0.2	40	118	0.02	.08	.03	<0.1
Hot Bubbling Pool (HBP)	05/24/72	60.0	7.2	3.3	0.1	380	25	382	120	250	11.0	300	1,532	0.34	13	2.5	-
	02/04/83	56.0	8.1	7.6	0.21	368	22	374	120	250	9.2	-	-	1.5	11	2.8	0.6
	11/17/83	55.0	8.0	11	0.23	335	23	399	110	238	10.3	207	1,188	.248	10.8	3.4	-
	05/25/85	69.3	7.6	8	0.04	396	21	376	120	244	10.6	215	1,271	1.5	11.1	3.0	<50
Chance-2 Well (CW-2)	05/28/85	104	9.0	2.6	0.16	362	20	348	111	233	9.8	173	1,109	1.3	10.6	3.0	<50
	06/03/85	92.5	6.0	1.4	0.10	290	20	290	88	210	8.7	140	936	1.2	9.1	2.1	3.5
Hot Creek Gorge Area - springs in section 25, T.3S., R.28E.																	
Morning Glory Pool (HC-1)	08/29/73	90.0	6.6	1.6	0.1	400	24	-	100	225	9.6	150	-	-	10.5	2.3	-
	05/29/80	92.0	7.8	2.4	0.08	395	23	484	94	220	10.0	142	-	-	10	-	0.2
	06/03/83	94.0	8.2	1.3	0.09	390	23	461	92	215	10.0	140	-	-	10	2.6	
	12/13/83	73.3	6.8	1.4	0.29	380	22	495	110	230	9.5	140	1,210	0.9	11	2.5	0.3
Spring above bridge (HC-2)	05/29/80	92.0	8.2	1.5	0.1	370	21	433	92	210	9.6	133	-	-	9.6	-	-
	01/11/83	90.0	7.6	-	-	-	-	-	-	210	-	-	-	0.96	-	-	-
	05/01/83	79.0	7.2	-	-	-	-	-	-	220	8.1	-	-	0.6	10	-	-
	06/03/83	82.0	7.3	7.0	0.26	375	23	441	98	210	10.0	140	-	-	10	2.5	-
	08/19/83	82.0	7.2	6.6	0.29	370	24	449	99	220	9.2	140	1,150	1.3	10	2.4	1.1
	10/04/83	79.1	7.2	6.4	0.22	370	21	450	100	220	9.7	140	1,140	0.98	10	2.4	0.3
	12/13/83	76.3	7.3	13.0	0.43	360	17	439	98	220	9.1	140	1,130	0.9	9.6	2.4	0.2
	05/08/84	79.2	7.3	6.5	0.20	360	24	435	100	220	9.8	130	1,150	0.9	9.5	2.7	0.1
	09/03/84	78.7	7.4	6.7	0.20	360	26	430	100	220	9.4	140	1,160	0.9	9.9	2.6	<0.1
	02/04/85	76.2	7.6	6.0	0.20	350	21	405	100	220	9.5	180	1,130	0.98	9.5	2.3	<0.1
	07/16/85	78.5	7.4	-	-	-	-	-	-	230	-	140	-	-	10.	-	-

Table 1-3. Chemical analyses of waters from selected springs and wells in the Long Valley area, Mono County, California (continued-pg.4)
(revised from Farrar, et al, 1985 & 1986) (Units are milligrams per litre)

Feature	Collection date	Temperature (°C)	pH	Ca	Mg	Na	K	ALK	SO_4	Cl	F	SiO_2	Dissolved Solids	As	B	Li	Hg
Hot Creek Gorge area - springs in section 25, T.3S., R.28E. (continued)																	
Geysers (HC-3)	03/16/83	89.0	8.4	3.6	0.30	380	23	475	95	220	11.0	-	-	0.99	11.	2.6	0.4
	05/01/83	90.0	7.9	-	-	-	-	-	-	230	10.0	-	-	0.8	11.	-	-
	08/19/83	91.5	8.0	2.4	0.22	380	24	473	96	230	9.9	140	1,180	1.1	10.	2.5	0.2
	11/18/83	90.0	8.2	2.9	0.22	353	23	475	105	176	6.9	165	1,131	1.6	9.8	2.8	
	12/13/83	88.3	8.2	3.7	0.20	380	24	471	94	230	10.0	140	1,150	0.9	11.	2.5	0.2
	05/08/84	91.4	8.1	2.3	0.20	380	24	490	96	230	10.0	130	1,190	0.9	9.8	2.9	0.2
	09/03/84	91.0	8.1	2.2	0.18	380	28	477	96	230	10.0	140	1,190	0.9	9.9	2.7	0.2
	11/12/84	90.2	-	-	-	-	-	-	-	220	10.0	-	-	-	10.	-	-
	02/04/85	92.0	8.1	2.5	0.20	380	23	474	98	230	13.0	180	1,170	0.9	9.9	2.4	0.2
	05/30/85	91.0	8.4	4.4	0.35	416	20	454	92	209	9.4	139	1,175	0.9	10.	2.9	<50
	07/26/85	92.8	7.8	4.4	0.20	410	22	457	98	220	9.7	140	1,190	1.1	10.	2.5	0.4
Hot Creek Gorge Area - wells in section 30, T.3S., R.29E.																	
CH-10	01/27/81	-	8.4	7.0	-	-	-	-	-	220	-	-	-	-	8.9	-	-
CH-10A	08/09/83	82.0	8.8	2.2	0.4	360	24	440	87	210	8.5	130	1,096	0.77	9.6	-	-
	11/09/84	93.3	7.2	-	0.4	340	21	463	93	200	8.4	230	1,120	0.62	9.9	2.3	0.2
CH-10B	08/16/83	83.0	8.4	6.7	0.3	360	22	435	90	200	9.5	130	1,090	1.2	9.	-	-
Shady Rest Well (preliminary analysis results)																	
SR Well	11/ /86	dh.		18	.35	388	48	-	-	260	-	105	-	-	9.9	.33	-
Laurel Spring (LS)	06/19/66	12.0	7.6	16	0	5	1.0	37	13	1	0.2	-	65	0.01	-	-	-
	06/03/83	12.0	8.6	16	0.6	5.9	1.3	40	18	0.5	0.1	-	-	.003	.02	.004	0.1
	11/17/83	10.0	8.8	14	0.6	5.3	1.2	37	17	0.4	-	20	-	.13	.05	-	-
	01/17/84	11.8	7.8	16	0.6	5.7	1.3	40	19	0.5	0.1	20	81	.004	.02	.005	0.1
	05/10/84	12.0	8.9	15	0.6	5.8	1.4	39	20	0.5	0.1	19	81	.004	.02	.006	0.1
	09/02/84	12.0	8.8	17	0.6	5.4	1.5	38	19	0.2	0.1	21	86	.003	.03	.005	<0.1
	02/02/85	12.0	8.9	17	0.6	6.2	1.3	38	19	0.6	0.2	22	85	.001	.02	.004	<0.1
	05/26/85	11.8	8.6	15.7	0.59	6.1	1.2	38	18.4	2.0	0.12	21	91	.2	.04	<.01	<50

Table 1-4

Stable Isotope Data from Springs & Wells
(From Farrar, et al, 1986)

Location	Date	δD	$\delta^{18}O$	
Casa Diablo Area				
Geyser (CDG)	6/26/83	-111.6	-13.5	
	11/18/83	-118	-13.2	boiled liquid
	6/29/84	-113.7	-13.6	
	9/ 4/84	-113	-13.5	
	5/29/85	-114	-13.5	
North Spring (CDWS)	6/26/83	-110.9	-12.8	
	12/15/83	-115	-14.3	
	5/ 9/84	-116	-14.3	
	9/ 4/84	-114	-14.2	
	2/ 6/85	-115	-14.0	
	7/16/85	-115	-14.1	
South Spring (CDSS)	2/ 4/83	-115	-14.3	
	3/15/83	-118.4	-14.7	
	6/ 3/83	-122	-14.8	
Well MPB-1	1/ 7/84	-114	-13.2	
	7/11/85	-128	-17.7	separated gas
	7/11/85	-116	-14.2	sep. liquid
	7/11/85	-117	-14.8	total flow liquid
Well IW-2	1/ 7/84	-128	-14.2	
MPB-5	1/ 5/84	-111	-13.4	
MPB-3	7/12/85	-116	-14.8	total flow liquid

Table 1-4, cont'd.

Location	Date	δD	$\delta^{18}O$	
Colton Spring Area				
Colton Spring	3/15/83	-112.5	-14.3	
	5/ 9/84	-115	-14.3	
	5/26/85	-115	-14.2	
Meadow Spring	3/15/83	-117.2	-15.1	
	5/10/84	-121	-15.1	
	5/26/85	-121	-13.7	
Well SS-2	11/17/83	-116	-15.1	
	7/16/85	-114	-15	
Fish Hatchery Area				
Springs 2,3	11/16/83	-128	-15.8	
	4/16/85	-124	-16.3	
	4/28/85	-123	-16.5	
Springs AB	4/28/85	-115	-15.2	
Springs CD	4/28/85	-118	-15.8	
Hot Bubbling Pool	6/26/83	-111.2	-12.4	
	6/28/84	-113.7	-13.1	
	5/28/85	-113	-13.2	
Well CW-2	5/28/85	-117	-14.3	sep. liquid
	5/28/85	-140	-18.9	separated gas
	5/28/85	-121	-15.2	total flow liquid

Table 1-4. cont'd.

Location	Date	δD	$\delta^{18}O$
Hot Creek Gorge Area			
Spring HC-1	6/ 3/83	-118.4	-14.9
	12/13/83	-118	-14.2
Spr. HC-2	6/ 3/83	-119.4	-14.2
	12/13/83	-117	-14.8
	7/16/85	-120	-14.7
Spr. HC-3	6/27/83	-120.6	-14.4
	9/ 3/84	-119	-14.8
	5//29/85	-121	-14.9
Laurel Spring (LS)	6/ 3/83	-123.7	-16.8
	9/ 2/84	-126	-16.9
	5/26/85	-127	-17.0

Table 2.1

Parameters Used for Heat Balance Calculation

Block	1	2	3	4
T_o (°C)	180	150	130	100
Volume (m^3)	$4.4 \times 10^9 m^3$	2.2×10^9	2.2×10^9	2.2×10^9
Q_{prod}	240 (1) 550 (2) 1170 (3)	-	- 620 (3)	-
Q_{inj}	240 (1) 550 (2) 1170 (3)	-	- 620 (3)	-
Q_{rech}	130 kg/s	-	-	-
T_{rech}	200 °C	-	-	-
Q_{spring}	-	-	30 kg/s	100 kg/s
T_{inj}	80°C	-	60°C	-

(1) MP I only
(2) MP I and PLES I case
(3) Cummulative case

General		
	Porosity	15%
	Rock Density	2600 kg/m^3
	Water Density	950 kg/m^3
	Rock Heat Capacity	240 cal/kg-°C
	Water Heat Capacity	100 cal/kg-°C

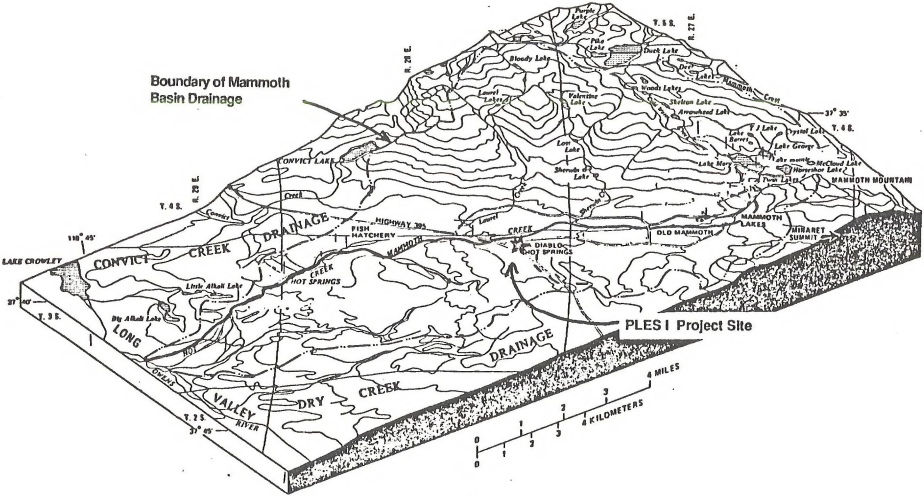

Boundary of Mammoth Basin Drainage
PLES I Project Site
Purple Lake
Pike Lake
Duck Lake
Bloody Lake
Deer Lake
Mammoth Crest
Woods Lakes
Shelton Lake
Arrowhead Lake
Laurel Lakes
Valentine Lake
Lost Lake
Sherwin Lake
T. 5 S.
R. 27 E.
R. 28 E.
37° 35'
T. 4 S.
TJ Lake
Crystal Lake
Lake Barrett
Lake George
Lake Mary
Lake Mamie
McCloud Lake
Horseshoe Lake
Twin Lakes
MAMMOTH MOUNTAIN
CONVICT LAKE
Convict Creek
Laurel Creek
Sherwin Creek
HIGHWAY 395
FISH HATCHERY
MAMMOTH CREEK
DIABLO HOT SPRINGS
OLD MAMMOTH
MAMMOTH LAKES
MINARET SUMMIT
T. 4 S.
R. 28 E.
118° 45'
LAKE CROWLEY
CONVICT CREEK DRAINAGE
HOT CREEK
HOT SPRINGS
Little Alkali Lake
Big Alkali Lake
37° 40'
T. 3 S.
LONG VALLEY
HOT CREEK DRAINAGE
OWENS RIVER
DRY CREEK
T. 2 S.
37° 45'
0
1
2
3
4 MILES
0
1
2
3
4 KILOMETERS

Figure 1-1 Surface Drainage Features of the Mammoth Creek Basin.

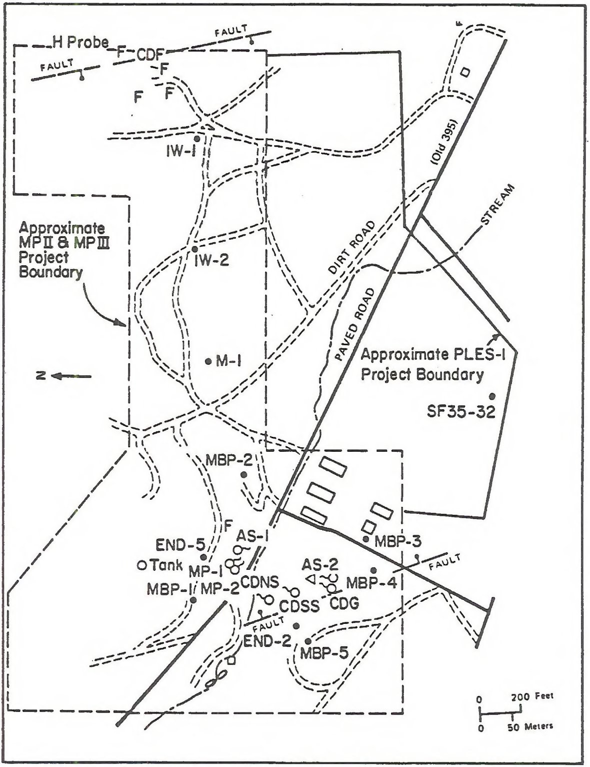
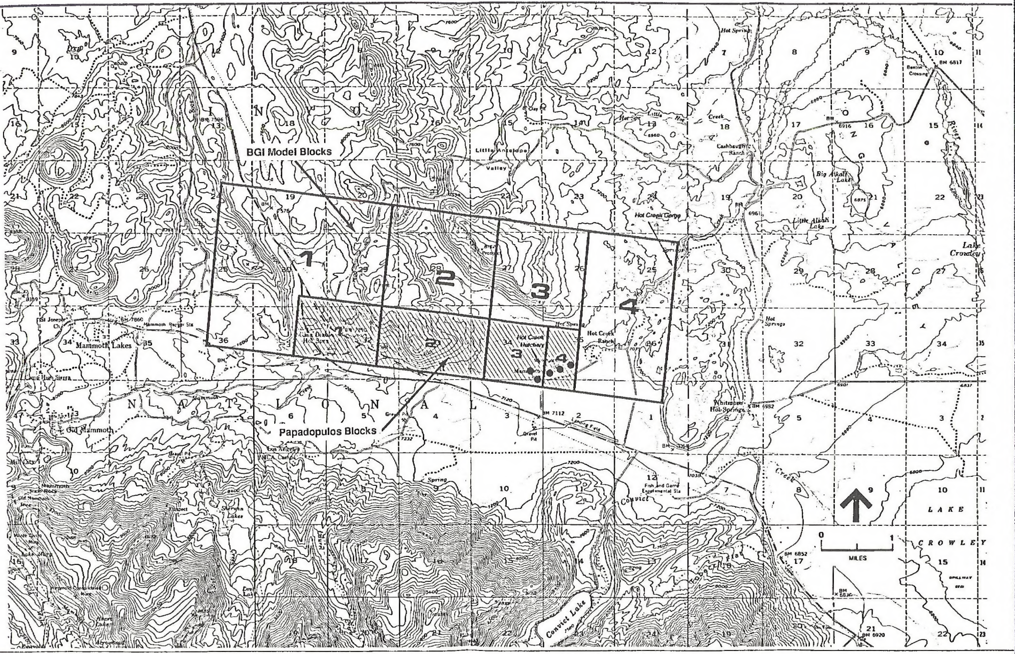

H Probe
F
CDF
FAULT
FAULT
F
F
F
IW-1
(Old 395)
STREAM
DIRT ROAD
Approximate MPII & MPIII Project Boundary
IW-2
PAVED ROAD
Approximate PLES-I Project Boundary
N
M-1
SF35-32
MBP-2
F
END-5
AS-1
MBP-3
Tank
MP-1
AS-2
FAULT
MBP-1
MP-2
CDNS
MBP-4
CDSS
CDG
FAULT
END-2
MBP-5
0 200 Feet
0 50 Meters

Figure 1-2. Map of the Casa Diablo Area showing the location of the proposed PLES I site, existing wells and springs.

(revised after Farrar et al, 1985)


BGI Model Blocks
1
2
3
4
Papadopulos Blocks
1
2
3
4
Mammoth Lakes
Old Mammoth
Hot Creek Gorge
Hot Creek Ranch
Hot Creek Hatchery
Casa Diablo Hot Sprs
Little Antelope Valley
Whitmore Hot Springs
Big Alkali Lake
Little Alkali Lake
Lake Crowley
Convict Lake
Benton Crossing
Hot Springs
Mammoth Rock
Fish and Game Experimental Sta
I N Y O
N A T I O N A L
LAKE CROWLEY
0
1
MILES

● Location of Convective Discharge

FIGURE 2-2 Comparison of Reservoir Simulation Blocks Used in the Heat Balance Calculation.

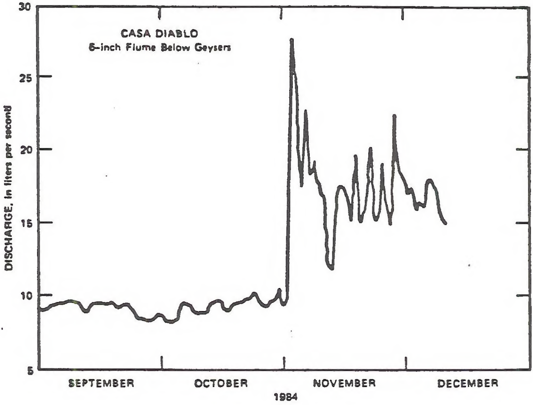
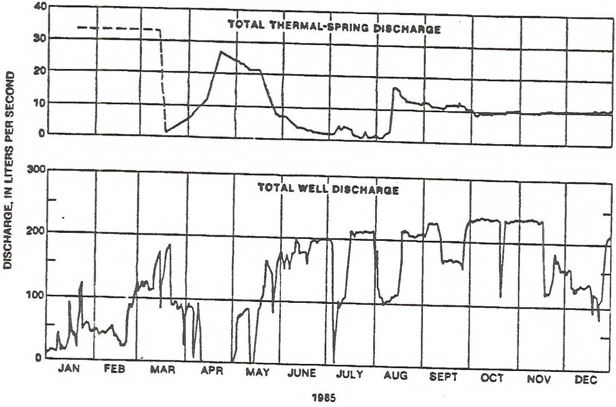


Figure 1-4. Flowrate of Casa Diablo Geyser (CDG) spring discharge, 1984.

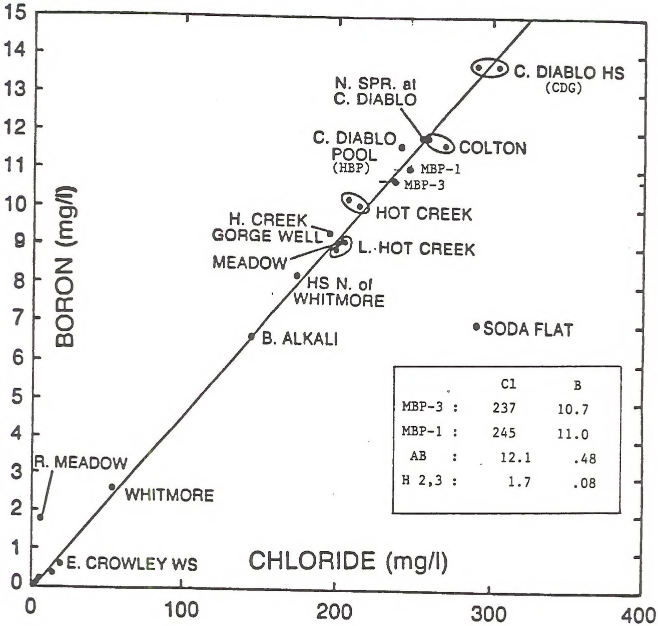
(after Farrar et al, 1985)



EXPLANATION

– – – EXTRAPOLATED DISCHARGE – From measurements made January 22 and March 18 and visual observations January 22-March 18

Figure 1-5. Flowrate of all Casa Diablo Springs during 1985.
(after Farrar et al, 1985)



	Cl	B
MBP-3 :	237	10.7
MBP-1 :	245	11.0
AB :	12.1	.48
H 2,3 :	1.7	.08

Figure 1-6. Plot of Boron vs. Chloride for selected spring and well waters.
(revised after Shevenell et al, in print)

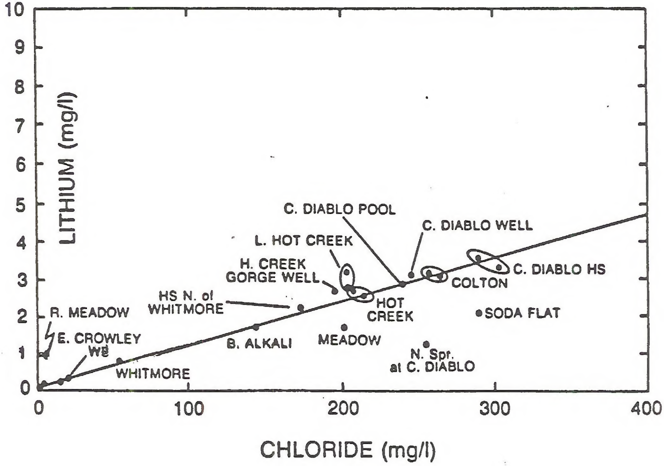


Figure 1-7. Plot of Lithium vs. Chloride for selected spring and well waters.

(after Shevenell et al, 1987, in print)

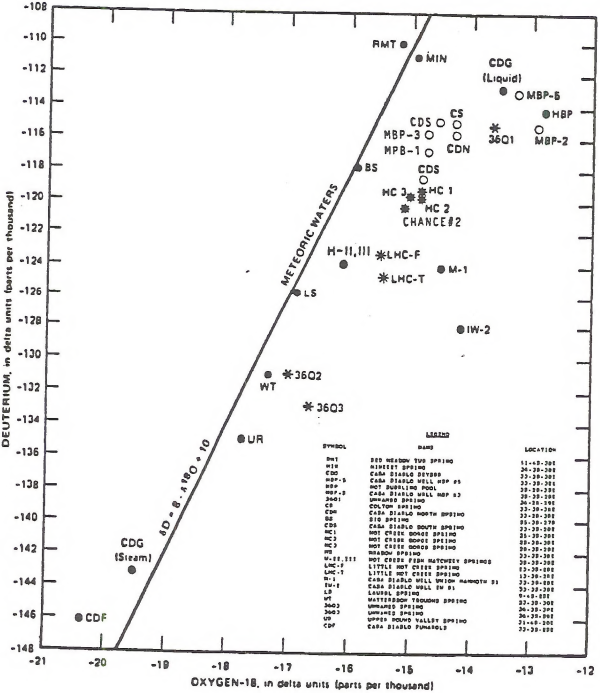


Figure 1-8. Plot of stable Hydrogen vs. Oxygen isotopes for selected spring and well waters.

(revised after Sorey et.al. 1984)

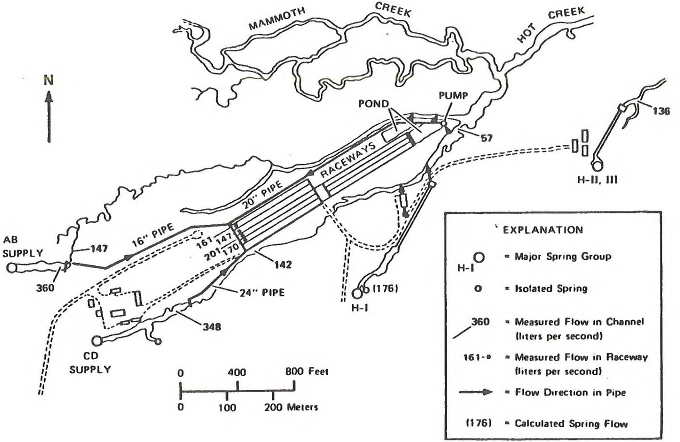

MAMMOTH
CREEK
HOT
CREEK
N
POND
PUMP
136
57
RACEWAYS
20" PIPE
H-II, III
16" PIPE
AB
SUPPLY
147
161
147
201
170
142
360
24" PIPE
(176)
H-I
348
CD
SUPPLY
0
400
800 Feet
0
100
200 Meters
EXPLANATION
H-I = Major Spring Group
= Isolated Spring
360 = Measured Flow in Channel (liters per second)
161- = Measured Flow in Raceway (liters per second)
= Flow Direction in Pipe
(176) = Calculated Spring Flow

Figure 1-9. Map of the Hot Creek Fish Hatchery including the location of springs. (after Farrar et al, 1985)

FIGURE 1-10 Temperature of Fish Hatchery AB Spring.

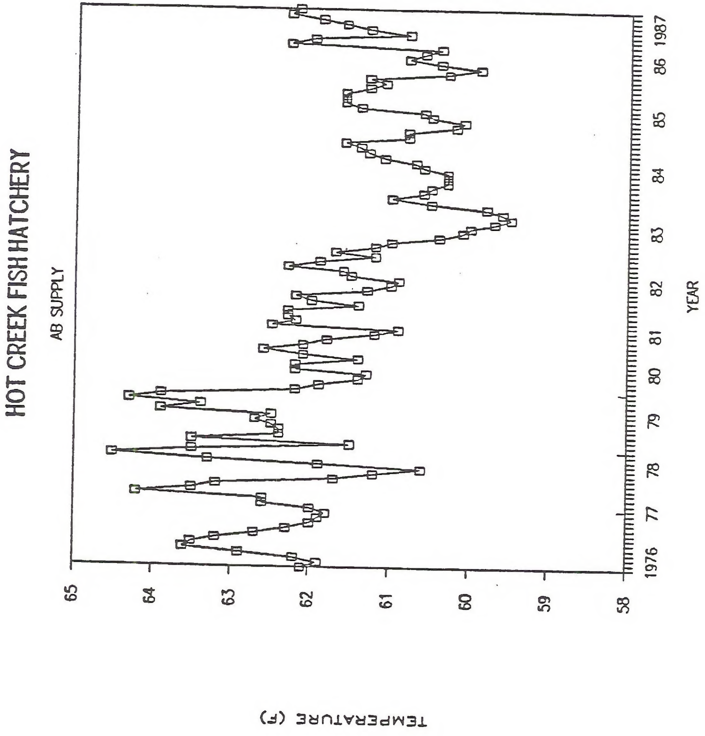


FIGURE 1-11 Temperature of Fish Hatchery CD Spring.

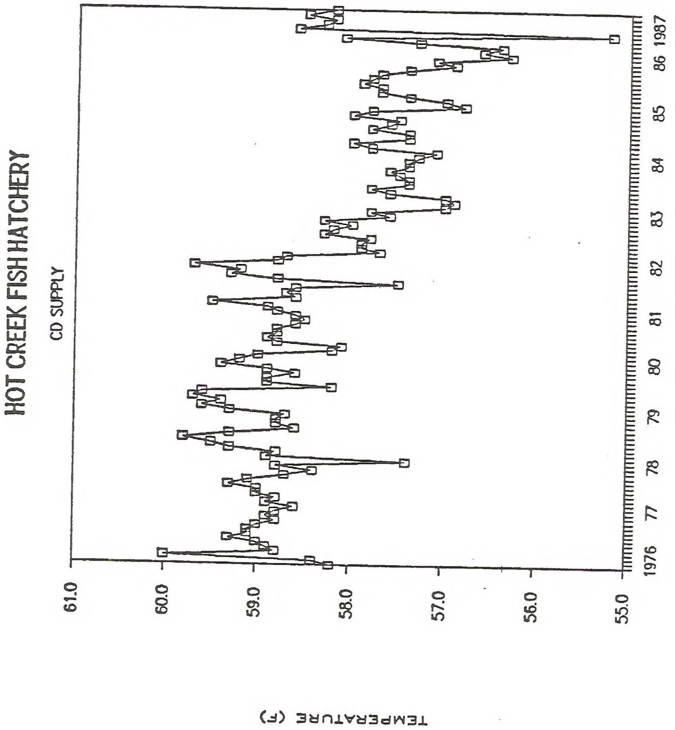


FIGURE 1-12 Temperature of Fish Hatchery I Spring.

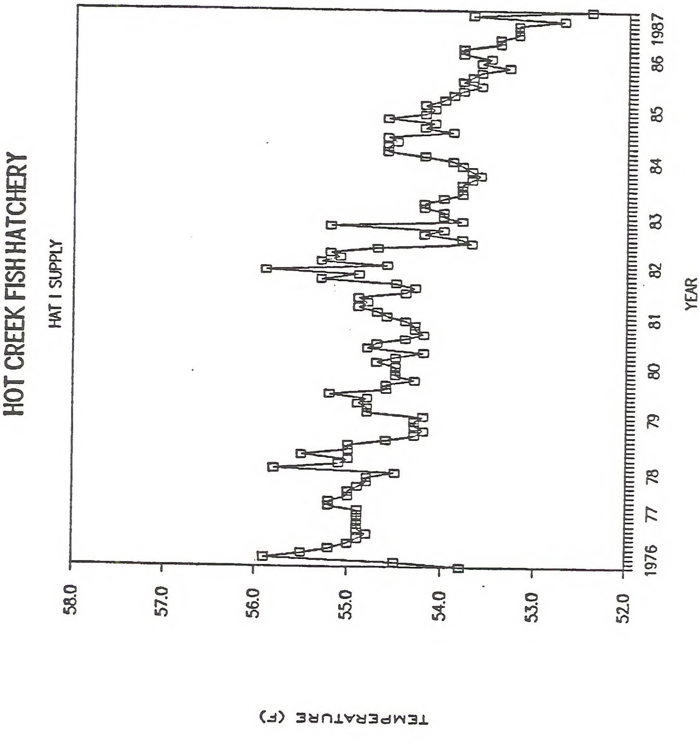


FIGURE 1-13 Temperature of Fish Hatchery II,III Spring.

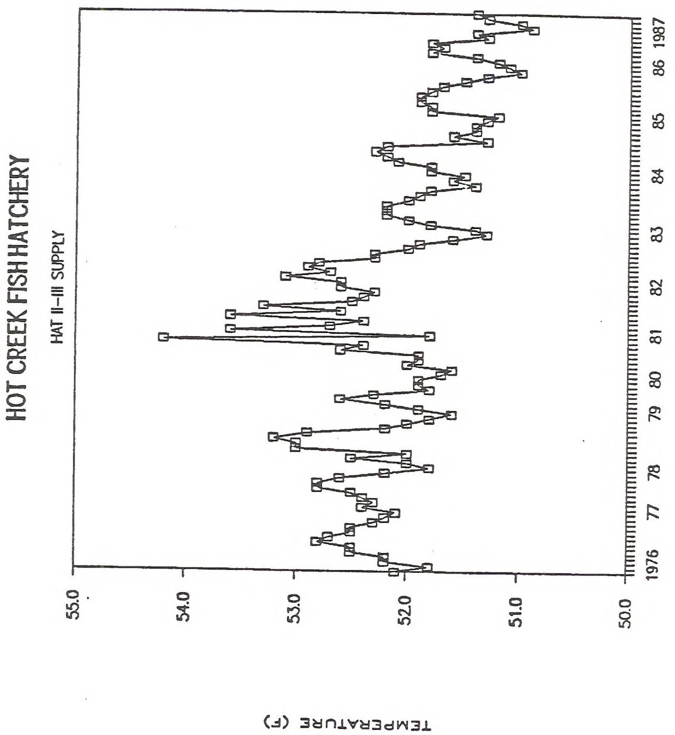
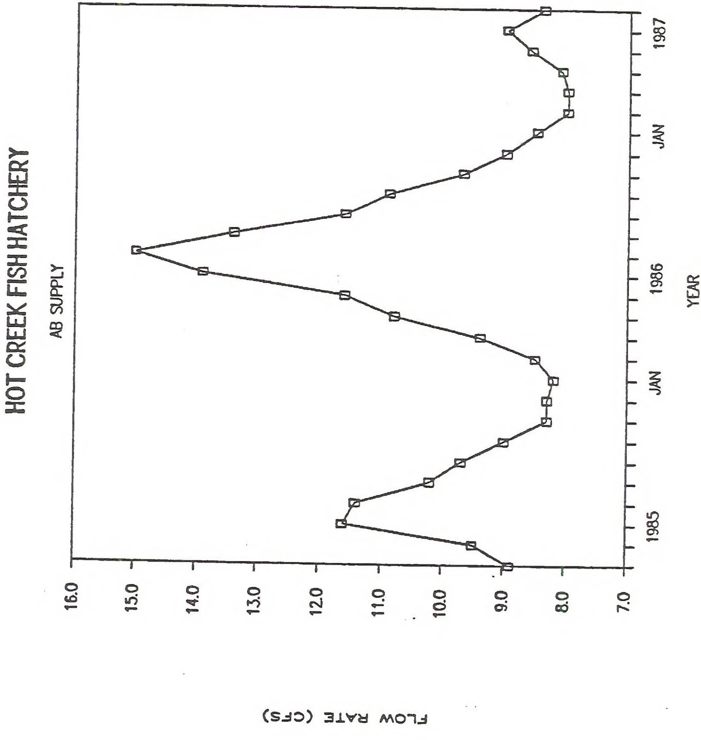


FIGURE 1-14 Flow rate of Fish Hatchery AB Spring.



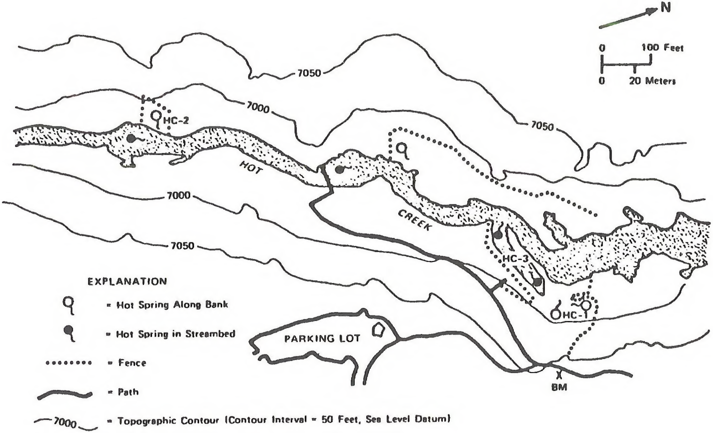

N
0
100 Feet
0
20 Meters
7050
7000
7050
HC-2
HOT
CREEK
7000
7050
HC-3
HC-1
PARKING LOT
BM
EXPLANATION
= Hot Spring Along Bank
= Hot Spring in Streambed
= Fence
= Path
7000
= Topographic Contour (Contour Interval = 50 Feet, Sea Level Datum)

FIGURE 1-15 Map of a part of Hot Creek Gorge, including the location of springs.

(after Farrar et al, 1985)

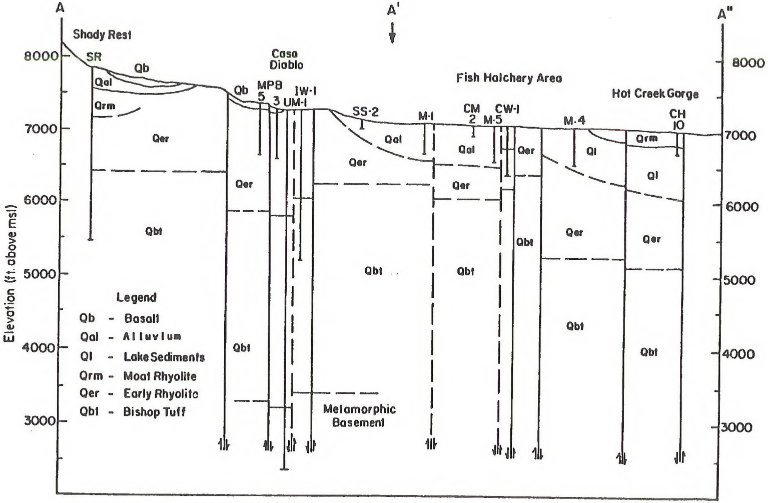

A
A'
A"
Shady Rest
SR
8000
7000
6000
5000
4000
3000
Elevation (ft. above msl)
Qb
Qal
Qrm
Qer
Qbt
Casa Diablo
MPB
5
3
IW-1
UM-1
Fish Hatchery Area
Hot Creek Gorge
SS-2
M-1
CM
2
M-5
CW-1
M-4
CH
10
Ql
Metamorphic Basement
Legend
Qb - Basalt
Qal - Alluvium
Ql - Lake Sediments
Qrm - Moat Rhyolite
Qer - Early Rhyolite
Qbt - Bishop Tuff

FIGURE 1-16 Geologic Cross-section along A -A'-A" from Figure 1-3, showing the location of selected wells.

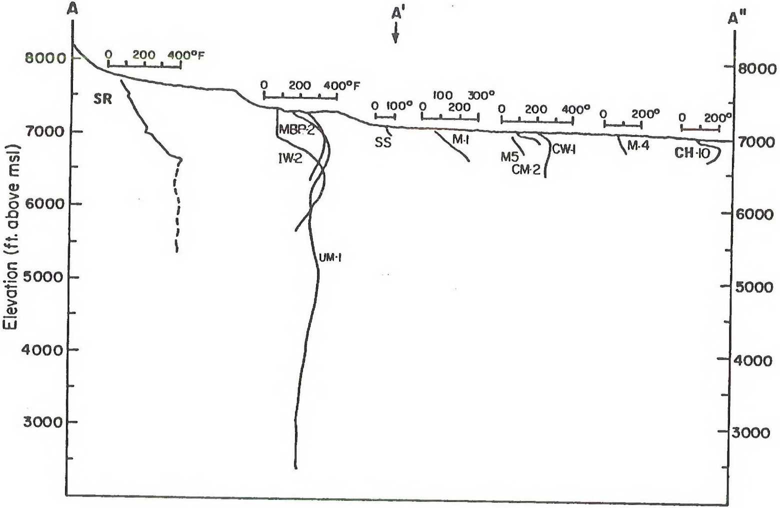
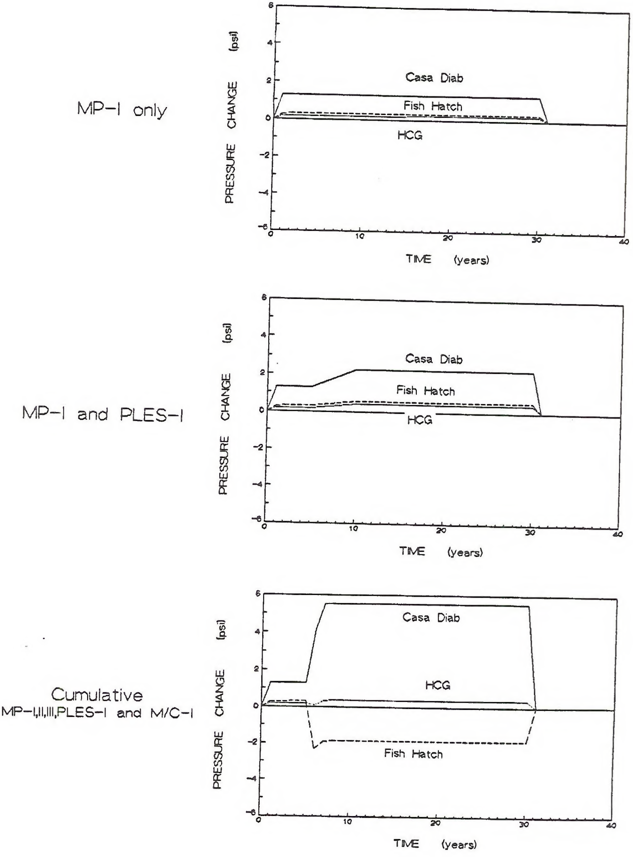

A
A'
A"
8000
7000
6000
5000
4000
3000
Elevation (ft. above msl)
0 200 400°F
SR
0 200 400°F
MBP·2
IW·2
UM·1
0 100°
SS
100 300°
0 200
M·1
0 200 400°
M5
CM·2
CW·1
0 200°
M·4
0 200°
CH·10
8000
7000
6000
5000
4000
3000

FIGURE 1-17 Cross-section along A-A'-A" from Figure 1-3, showing selected well temperature profiles.

FIGURE 2-1 Calculated Reservoir Pressure Response in the Casa Diablo, Hot Creek Gorge and Fish Hatchery Areas.



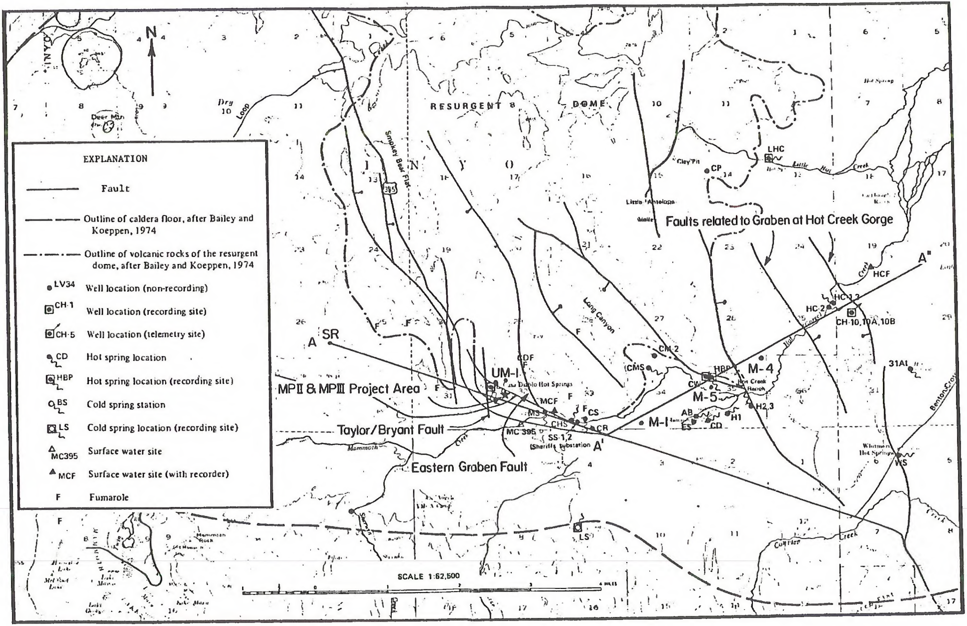
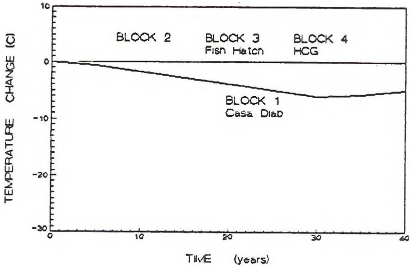

EXPLANATION
Fault
Outline of caldera floor, after Bailey and Koeppen, 1974
Outline of volcanic rocks of the resurgent dome, after Bailey and Koeppen, 1974
LV34 Well location (non-recording)
CH-1 Well location (recording site)
CH-5 Well location (telemetry site)
CD Hot spring location
HBP Hot spring location (recording site)
BS Cold spring station
LS Cold spring location (recording site)
MC395 Surface water site
MCF Surface water site (with recorder)
F Fumarole
N
RESURGENT DOME
Faults related to Graben at Hot Creek Gorge
MPII & MPIII Project Area
Taylor/Bryant Fault
Eastern Graben Fault
A
SR
A'
A''
UM-I
M-1
M-4
M-5
LHC
CP
HCF
HC-1,2
HC-2
CH-10,10A,10B
HBP
CW
CMS
CM-2
CDF
MCF
M3
CHS
CS
CR
MC 395
SS-1,2
(Sheriffs Substation)
AB
ES
CD
H1
H2,3
31At
WS
LS
Casa Diablo Hot Springs
Hot Creek Ranch
Long Canyon
Smokey Bear Flat
Deer Mtn
Dry Loop
Clay Pit
Little Antelope Valley
Little Hot Creek
Hot Creek
Mammoth Creek
Whitmore Hot Springs
Benton Crossing
Convict Creek
Sherwin Creek
Mammoth Rock
INYO
395
SCALE 1:62,500
0
1
2
3
4 MILES

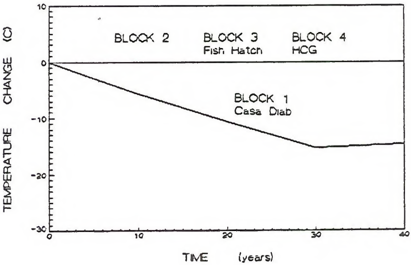
Figure 1-3. Map of the southern region of the Long Valley Caldera showing the location of the proposed MP II and MP III sites, faults, thermal features, wells and the trace of cross-section for Figures 1-11 and 1-12.

FIGURE 2-3 Calculated Reservoir Temperature Changes in the Casa Diablo, Hot Creek Gorge and Fish Hatchery areas.

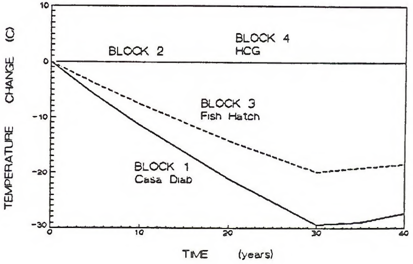
MP-I only



MP-I and PLES-I



Cumulative
MP-I,PLES-I,MP-II,
MP-III and M/C-I



APPENDIX D

BIOLOGICAL SURVEYS

BIOTIC ASSESSMENT FOR PROPOSED GEOTHERMAL ENERGY FACILITIES, CASA DIABLO HOT SPRINGS, MONO COUNTY, CALIFORNIA

Biotic Assessment
Casa Diablo Geothermal

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Pacific Lighting Energy Systems
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Commerce, CA 90040

January 12, 1987

J-302

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1.0 INTRODUCTION

This report provides an inventory of biotic resources for the site of proposed geothermal energy resource developments near Casa Diablo Hot Springs in Mono County, California. This region is one of existing and proposed electrical generation facilities utilizing hot water derived from volcanic sources.

Environmental Management Associates, Inc., on behalf of Pacific Lighting Energy Systems (PLES) has subcontracted with BioSystems Analysis, Inc. (BSAI) to conduct a baseline biological inventory and assessment of the Casa Diablo Hot Springs area and vicinity. The results of this survey will be used as baseline information and background for biological impact assessment for environmental reports in relation to proposed geothermal development. This report presents the results of BSAI's inventory, characterization, and assessment of the biotic resources of the Casa Diablo Hot Spring area.

2.0 STUDY AREA DESCRIPTION

2.1 GEOGRAPHIC SETTING

The Casa Diablo Hot Spring study area consists of approximately 623 acres (252 ha). The exact boundary of the study area in which biological resources were studied is shown in Figure 1.

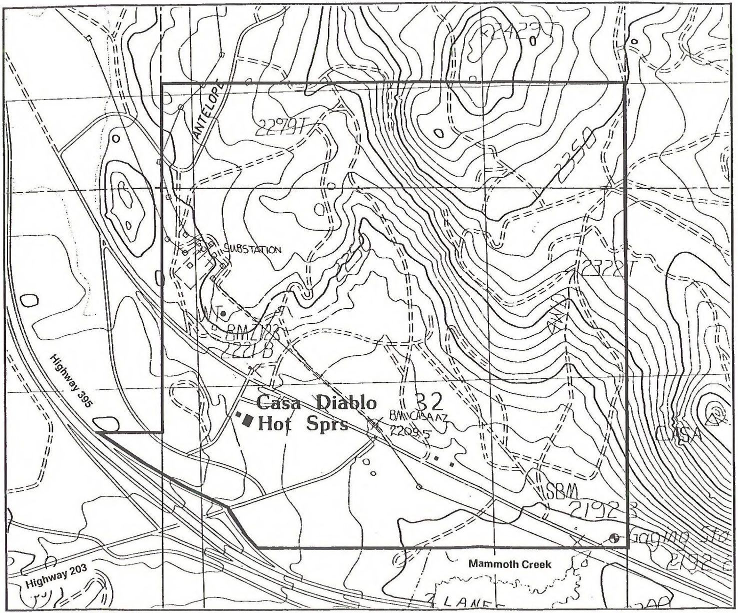
Location - The study area is located in Township 3 South, Range 28 East (Mount Diablo Base Line & Meridian) in portions of Section 28, Section 29, Section 32 and Section 33 (Figure 1).

Vicinity - Casa Diablo Hot Springs is located adjacent to and east of Highway 395 approximately 35 miles north of Bishop and 25 miles south of Lee Vining, situated near the junction with Highway 203. The site is about 4 miles east from the town of Mammoth Lakes.

Land Ownership - most lands adjacent to and within the study area are administered by the U.S. Department of Agriculture, Forest Service, being situated on the Mammoth District of the Inyo National Forest. Approximately 90 acres of the site are in private ownership under geothermal lease. The remaining federally administered area is leased for geothermal energy development, with administration of said leases under the direction of the Bureau of Land Management.

2.2 PHYSIOGRAPHY AND REGIONAL CLIMATE

The study area is located at the eastern base of the Sierra Nevada, bordering the boundary between the Sierra Nevada and Great Basin physiographic provinces. As situated, Casa Diablo Hot Springs and the Mammoth region in general is located in a portion of the Sierra where the crest is relatively low in elevation compared to areas directly to the north or south. As a consequence, the area to the north of Casa Diablo Hot Springs is heavily forested, contrasting markedly with the otherwise sagebrush dominated deserts to the east and south.


ANTELOPE
2279T
2429T
2250
SUBSTATION
BM 2123
2221 B
2322T
Casa Diablo
Hot Sprs
32
BM CASA AZ
2209.5
CASA
SBM
2192.3
Gaging Sta
2192
Highway 395
Highway 203
Mammoth Creek
3 LANE

(Source: 1983 U.S.G.S. Old Mammoth Quadrangle)

Figure 1. Location Map

STUDY AREA BOUNDARY

SCALE 1:8,615

0 850 1700

FEET

N

Elevations within the study area range from 7200 feet to 7900 feet. Relief on the western and southern portions of the site is moderate, with hills and steeper slopes to the east (Figure 1).

The relatively mesic climate in the vicinity of Mammoth can be attributed largely to the low elevation of the Sierran crest to the east, allowing storms from the west to penetrate through the nearby passes (cf. Smith 1976). Winter climate at the vicinity of Casa Diablo Hot Springs is characterized by abundant snowfall and cold temperatures. Snow pack depth at maximum extent is about 3 feet in years of average precipitation. Annual precipitation in the vicinity of Casa Diablo Hot Springs is on the order of 25 inches. Winter temperatures are generally in the 10°F-30°F range, while summer temperatures are generally in the 40°F-70°F range.

2.3 GEOLOGY

The study area is situated in a region of active recent vulcanism (Bailey et al. 1976). Casa Diablo Hot Springs is located on the southwestern margin of the Long Valley caldera, a large volcanic depression at the headwaters of the Owens River in which present-day Crowley Lake is located. The source of energy driving the thermal features at Casa Diablo Hot Springs and elsewhere in the region is a residual magma deposit underlying the region at a fairly shallow depth (Miller 1985, Storey et al. 1978).

Surface rocks exposed within the study area consist largely of rhyolite, tuff and basalt deposits (Bailey and Koppen 1977). Small exposures of hydrothermally altered rocks occur about the area that are rich in clays, and small travertine deposits occur in association with the hot springs proper.

3.0 SURVEY METHODS

Selection of methodology appropriate for identification of biotic resources of the Casa Diablo study site was made after consultation with agency personnel. Unpublished information for this biotic assessment was gathered from files of appropriate government agencies. Table 1 provides an enumeration of agency personnel contacted during the biotic assessment process.

3.1 REVIEW OF LITERATURE AND DATA SOURCES

Publications and documents on the vegetation and wildlife of Mono County and specifically the Mammoth region were assembled and reviewed, and information was gathered from local agency experts prior to fieldwork. Previous environmental and planning documents for the region were reviewed, including the Mammoth-Mono Planning Unit Plan (U.S. Forest Service 1978), the draft Inyo National Forest Plan (1986), and U.S. Forest Service environmental assessments related to leasing of potential geothermal sites within the Long Valley caldera (USFS 1980, 1982).

Literature on the wildlife of the region, including status, habitat relationships, and management considerations was collected form various sources (cf. Remsen 1978, Laudenslayer and Grenfell 1983, Verner and Boss 1980). Specific consideration was given to obtaining information on species of special concern with potential occurrence within the study area. These include sensitive species (having special legal or management status): federally endangered or threatened, federal candidate species, California state threatened or endangered, California state fully protected, and Department of Fish and Game bird species of special concern. Species with commercial or local recreational importance can also be considered species of concern.

Wildlife habitat analysis was completed based on indicator species that represent guilds, or groups, of wildlife that depend on similar habitat for survival.

Table 1.

Enumeration of government agency personnel contacted during the Casa Diablo Hot Springs biotic assessment.

Agency	Contact
U.S. Forest Service	Clint McCarthy, Forest Wildlife Biologist
	Cristina Hargis, Mono Ranger District Biologist
California Department of Fish and Game	Edwin P. Pister, Fisheries Biologist
	Ron Thomas Wildlife Biologist
	Tom Blankenship, Wildlife Biologist

3.2 VEGETATION METHODS

The Casa Diablo Hot Springs vegetation survey was divided into three activities

- Preliminary literature and Data Base review
- On-site rare plant searches
- Habitat type mapping

Prior to conducting field work, a literature review was undertaken to gather and evaluate information on the rare plant species and sensitive habitats with known occurrences in the region. The basic working list for the rare plant survey was a list of all California Native Plant Society (CNPS) rare and endangered plants of California with occurrences in Mono County (Smith and York 1984). To develop a list of potential rare plants possibly occurring at the site, the working list was refined using geographic distribution and habitat information provided in standard floristic manuals (i.e., Munz and Keck 1968, Cronquist et al. 1972, 1977, 1984), location data printouts from the California Natural Diversity Data Base (CNDDB, Cochrane and Jensen 1984), and from unpublished rare plant status reports prepared for the CNPS (various authors).

Table 2 presents status, habitat, and distributional information for 12 CNPS rare or endangered plants with potential to occur in the vicinity of Casa Diablo Hot Springs. This table presents a refined working list for field surveys, based upon the data review described above.

Rare plant surveys were conducted on the site on 25 November 1986 and 26 November 1986. Potential habitat areas were surveyed for rare plant populations, and a vascular plant species list was compiled to aid in habitat characterization and sensitive habitat assessment.

Mapping of vegetation types within the study area was conducted using standard techniques (Avery 1968). Color aerial photography of the study area was used to map vegetation (source: 1984 U.S. Forest Service photos). Polygons of uniform habitat conditions were drawn on an overlay of the photography (scale ca. 1:8,000). The study area was then surveyed on foot and by vehicle to inspect vegetation conditions, and a preliminary map drawn. The map was then transferred to a topographic base map of the area (1983 Mammoth Quadrangle, U.S.G.S. interim edition) using a Bausch & Lomb Stereo Zoom Transfer scope with the aid of 1:16,000 aerial photography (source U.S. Forest Service, 1972 photography).

Table 2. Rare plants potentially occurring in the Casa Diablo Hot Springs region.

Species (1)	U.S.F.S. Status (2)	U.S.F.W.S. Listing (3)	State Status (4)	CNPS Status (5)	Habitat Type (6)	Substrate (7)	Elevation Range (8)	Known Distribution (9)	Flowering Period (10)
Astragalus monoensis Mono milkvetch	Sensitive	Category 1	Rare	2-2-3 List 1B	Sagebrush flats	pumice soils	6700-11,000	Mono	May-July
Astragalus johannis-howellii Howell's locoweed	None	Category 3C	Rare	2-2-2 List 1B	Sagebrush scrub	travertine or rhyolite	7000,8000	Mono [NV]	May-July
Astragalus lentiginosus var. piscensis / Fish Slough milkvetch	None	Category 1	None	3-2-3 List 1	Alkali sink	pH > 8.5	ca. 5000	Mono	July
Centaurium namophilum Nevada Centuray	None	None	None	1-1-3 List 4	Alkali sink	springs and seeps	above 4000	Mono, Inyo [NV, OR]	April-July
Eriogonum ampullaceum Mono Buckwheat	Sensitive	Category 2	None	2-2-3 List 1B	Sagebrush scrub and meadow borders	alkaline soils	5500-7500	Mono [NV]	May-July
Fimbristylis spadicea Hot Spring Sedge	None	Category 3c	None	2-2-1 List 2	Alkali sink	hot springs	2500-5500	Inyo, Mono, San Bernardino	April-June
Lupinus duranii Mono Lake lupine	None	Category 2	None	1-1-3 List 4	Sagebrush scrub & Jeffrey Pine	pumice soils	6500-9500	Mono	May-July
Lupinus montigenus Pumice Bush Lupine	None	None	None	None App. 1	Jeffrey Pine & Sagebrush	snowbanks	6000-10,000	Mono, Inyo [NV]	May-August
Lupinus sublanatus Mammoth Lupine	None	None	None	1-1-3 List 3	Jeffrey Pine	unknown	ca. 8000	Mono	July?

Table 1 (continued).

Species (1)	U.S.F.S. Status (2)	U.S.F.W.S. Listing (3)	State Status (4)	CNPS Status (5)	Habitat Type (6)	Substrate (7)	Elevation Range (8)	Known Distribution (9)	Flowering (10)
Pedicularis crenulata var. candida / Scolloped Lousewort	Sensitive	None	None	3-1-1 List 2	meadows	organic soils	ca. 7500	Mono [to Rocky Mountains]	June-August
Sedum pinetorum Pine City Stonecrop	None	Category 2	None	None App.1	pine forest	"in the duff"	ca. 8500-9500?	Mono	July?
Sidalcea covillei Owens Valley checkermallow	None	Category 2	Endg.	2-2-3 List 1B	Alkali sink	meaodw borders	4000-5500	Inyo	May-July

NOTES:

1. Nomenclature for scientific names and common names follows Smith and York (1984).
2. U.S. Forest Service management status (Region 5, Forest Service Manual, Title 2600).
3. Notice of Intent (50 CFR Part 17, Federal Register Vol. 50, No. 188, 27 September 1985).
   Federal Status designations are as follows:
   Category 1 = currently under review with extisting information sufficient to support listing as endangered or threatened.
   Category 2 = currently under review with extisting information insufficient to support listing.
   Category 3c = currently not under review, as taxon is more common than formerly thought.

4. California Department of Fish and Game, Designated Endangered or Rare Plants (26 March 1985)
5. Smith and York (1984). CNPS Listr 1B = Plants rare or endangered in California and elsewhere.
   List 2 = plants rare in California but more common elsewhere. List 3 = plants needing more information;
   List 4 = plants rare but not endangered in California. The R-E-D Code (Rarity-Endangerment-Distribution)
6. Based on Dedecker (1984) and field observations.
7. Based on field observations.
9. CNDDB records and Munz (1959, 1968).
10. Field observations.

3.3 FIELD SURVEYS FOR TERRESTRIAL WILDLIFE

Field surveys were conducted on foot and by vehicle on 19 and 20 November, 1986. Representative sections of different habitat types that occur on the project area were evaluated. Areas of unique habitat and wildlife potential were identified and mapped. Special emphasis was placed on determining habitat suitability for and occurrence of Species of Concern and indicator species.

For the purpose of this study, the survey area includes the private inholdings containing the existing geothermal powerplant and the hot water wells associated with the development, as well as the U. S. Forest Service land. The presence of a species was confirmed either by sighting of an individual animal, evaluating scat or tracks, or by the call of the animal. During the survey all wildlife observations were recorded in field notebooks. A species list was also prepared of all wildlife observed or expected to occur on the site (because of the dates of the survey, we were unable to document the breeding of any species on the site, as most of the birds that breed on site have already fledged young and many of the migratory birds had already departed). In general, behavior was less conspicuous at the season of the survey, making field observation more difficult.

No quantitative assessments of habitat parameters were measured on the study area. The field visits provided only qualitative assessments of habitat suitability. These qualitative assessments were then compared to quantitative data in the literature and a subjective assessment of habitat suitability was made for each species or guild of concern. The shortcomings of this subjective assessment are fully recognized; the scope of the study requested to date precludes more detailed analysis of the habitat.

4.0 RESULTS

4.1 FLORA

The Casa Diablo Hot Springs area is located on the boundary between the Californian and Great Basin biogeographic provinces. Consequently, the flora is composed of largely two distinct elements: mountain and desert plants. There is no specific local flora covering Mono County, and the eastern Sierra region is as yet poorly understood floristically. The plant checklists for the Owens Valley region compiled by Dedecker (1974, 1984) are the most valuable local source of floristic information. Other plant checklists have been published in grey-literature sources for several areas adjacent to the Casa Diablo region: Convict Creek basin (Major 1964), lower Convict Creek (Orr 1981), for a small area near Mammoth (Howald 1981), for nearby Indiana Summit Research Natural Area (Taylor 1980) and adjacent portions of Glass Mountain Ridge (Dedecker 1979), and for the Mono Basin (Taylor 1981).

A list of vascular plant species observed on the study area is presented in Appendix 1. Due to the dates of our survey (late November), most of the annuals and herbaceous perennials growing on the site were dormant and consequently were easy to overlook.

4.1.1 HABITAT TYPES AND VEGETATION MAPPING

A total of 10 major vegetation types were observed on the Casa Diablo Hot Springs study area:

- Jeffrey Pine Forest
- Jeffrey Pine-Pinyon Pine Woodland
- Pinyon-Juniper Woodland
- Sagebrush Scrub
- Black Sagebrush Scrub
- Rhyolite Buckwheat Scrub
- Thermal Marsh
- Yellow Willow Riparian Thicket
- Nebraska Sedge Meadow
- Ruderal & Disturbed Weed field

Figure 2 provides a map depicting the distribution of these major habitat types within the study area boundaries. The majority of the study site

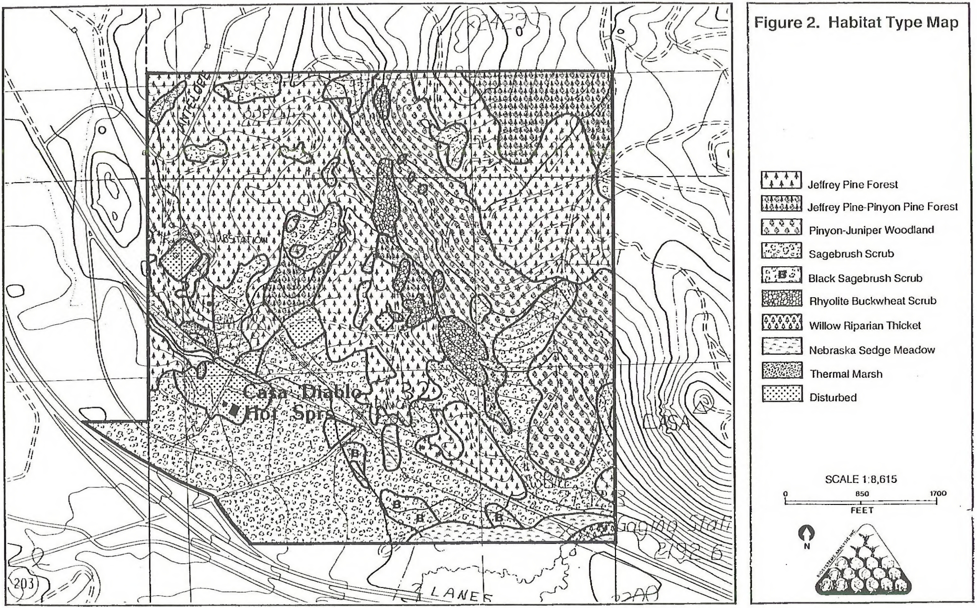
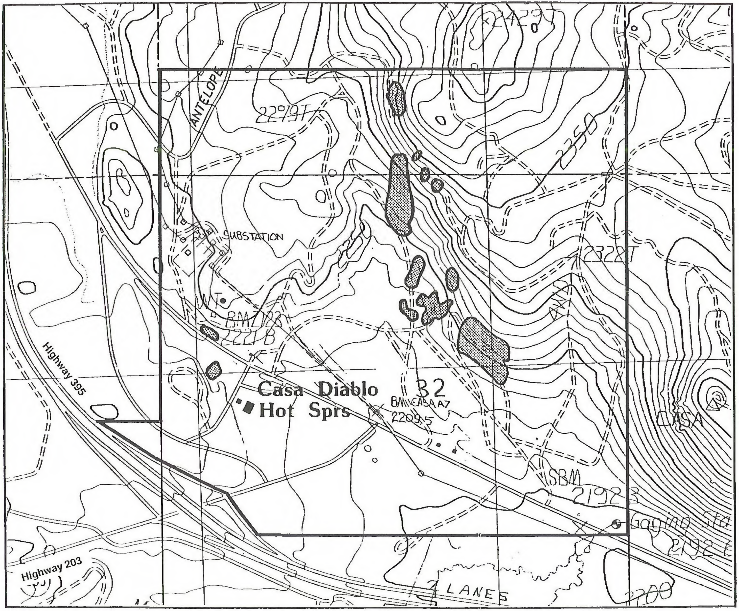


Figure 2. Habitat Type Map

ANTELOPE
SUBSTATION
Casa Diablo
Hot Spr
32
CASA
Gaging Stat
2192.6
LANES
203
B
▨ Jeffrey Pine Forest
▨ Jeffrey Pine-Pinyon Pine Forest
▨ Pinyon-Juniper Woodland
▨ Sagebrush Scrub
B Black Sagebrush Scrub
▨ Rhyolite Buckwheat Scrub
▨ Willow Riparian Thicket
▨ Nebraska Sedge Meadow
▨ Thermal Marsh
▨ Disturbed
SCALE 1:8,615
0
850
1700
FEET
N
BIOSYSTEMS ANALYSIS INC.

(Source: 1983 U.S.G.S. Old Mammoth Quadrangle)

Figure 3. Sensitive Habitats


ANTELOPE
2279T
2242
2350
SUBSTATION
2322T
BM 2213
2221 B
Casa Diablo
Hot Sprs
32
BM CASA A7
2209.5
CASA
SBM
2192.3
Gaging Sta
2192
Highway 395
Highway 203
2 LANES
2200

▨ Botanically Sensitive Areas

SCALE 1:8,615

0
850
1700
FEET
N

(Source: 1983 U.S.G.S. Old Mammoth Quadrangle)

consists of forest and woodland vegetation, with Jeffrey Pine (*Pinus jeffreyi*) and Pinyon Pine (*Pinus monophylla*) dominating. The second most important habitat-type on the site is scrub vegetation, with Sagebrush (*Artemisia tridentata* ssp. *vaseyana*) dominant. The remainder of the habitat types observed on the site cover but a small proportion of the landscape, but are nonetheless distinct and important components of the vegetation.

Jeffrey Pine Forest - a moderately dense (30%-60% canopy cover) forest stand type, with a single overstory dominant, *Pinus jeffreyi*, covers much of the study site. This forest is variable in tree density and basal area over the study area, but in general most stands on the site are young and relatively open canopied. Subjective age estimates (cf. Taylor 1980) indicate most of the forest stands on the site are less than 80 years old, with the exception of the far northeastern corner of the site, where old-growth forest conditions (i.e., > 150 yr old stands) occur. Understory in Jeffrey Pine Forest consists of a dense to moderately open shrub layer composed of sagebrush and bitterbrush (*Purshia tridentata*), with some sites having tobacco bush (*Ceanothus velutinus*). Grass cover in this forest type is low, with squirrel tail (*Sitanion hystrix*) being most important.

Jeffrey Pine - Pinyon Pine Woodland - this woodland is intermediate in composition and structure between Jeffrey Pine Forest and Pinyon-Juniper Woodland. The nature of this woodland is such that it represents a successional stage in forest development, where Jeffrey Pine stands become established within pinyon woodland, and will eventually dominate absent subsequent disturbance such as from wildfire.

Pinyon-Juniper Woodland - steep slopes on the eastern portion of the study area are vegetated by a woodland (20%-40% canopy cover) dominated by pinyon pine (*Pinus monophylla*) with some Sierra juniper (*Juniperus occidentalis* ssp. *australis*). Canopy height in this woodland is generally less than 35 feet. Understory vegetation in this type is similar to Jeffrey Pine Forest, but with greater abundance of rabbitbrush (*Chrysothamnus nauseosus*) and a variety of forbs and grasses (including locally high cover of *Bromus tectorum*).

Sagebrush Scrub - the southwestern portion of the study area is vegetated by stands of sagebrush (*Artemisia tridentata* ssp. *vaseyana*) scrub. Shrub cover averages about 30%-50%, with moderate cover of cheatgrass (*Bromus tectorum*). Companion shrubs in this community include bitterbrush (*Purshia tridentata*), rabbitbrush, horsebush (*Tetradymia canescens*) and sulfur-flower (*Eriogonum umbellatum*). Canopy height in this vegetation ranges from 2 to 4 feet. In years of good spring rains, this community can support a diverse assemblage of annual herbs, few of which were in evidence on the site at the time of our survey.

Black Sagebrush Scrub - a distinct vegetation type in the eastern Sierra but relatively uncommon in the vicinity of the study area. Several patches of black sage (*Artemisia nova*) scrub occur on basaltic rocks in the extreme southwestern portion of the site. Canopy cover and associated flora in this vegetation is similar to Sagebrush Scrub, but canopy height is much less, averaging less than two feet.

Rhyolite Buckwheat Scrub - a distinct habitat of limited distribution in the eastern Sierra region. Vegetation cover at this type of site is low, with large clumps of Rhyolite Buckwheat (*Eriogonum kennedyi* var. *purpursii*) being conspicuous. Associated herbs are many, with Pussy-paws (*Calyptridium umbellatum*), locoweed (*Astragalus purshii*) and cheatgrass the most important. This community type is restricted to present or formerly thermally affected soils, and is essentially limited to the region.

Thermal Marsh - a marsh community composed of sedges (*Scirpus americanus*, *S. nevadensis*), rushes (*Juncus balticus*) and grasses (*Muhlenbergia asperifolia*, *Distichilis spicata*, *Hordeum jubatum*, *Poa juncifolia*) that is found about many of the thermal springs in the Mono Basin, Long Valley and Owens Valley region. Height of the graminoid canopy in this vegetation is less than 2 feet, while cover is high, except where excessive deposits of evaporites or open water limit vegetation development.

Yellow Willow Riparian - a riparian thicket that is a common and typical riparian vegetation type in the eastern Sierra (Taylor 1982) occurs on the southern boundary of the study area along Mammoth creek. Vegetation in this habitat type is dominated by yellow willow (*Salix lutea*) sandbar willow (*S. exigua*) and Great Basin wild rose (*Rosa woodsii* var. *ultramontana*), with a lush and diverse herbaceous understory. At the time of our survey of the site, most of the understory species of this vegetation were dormant, or were so heavily grazed, that their identification was difficult. The most important graminoid in this community that we observed was *Carex nebrascensis*.

Nebraska Sedge Meadow - a large wet meadow occurs just at the southern boundary of the study area. The vegetation of this meadow is dominated by Nebraska Sedge (*Carex nebrascensis*), with Great Basin Iris (*Iris missouriensis*) and rush (*Juncus balticus*) important codominants. A marginal scrub community typical of such meadows in the Long Valley region occurs at the dry margin of the meadow dominated by *Artemisia cana* ssp. *bolanderi* and *Chrysothamnus nauseosus*.

Ruderal and Disturbed Weed field - areas of recent or frequent surface soil disturbance at the study site are very sparsely vegetated. Where soil disturbance allows any plants whatsoever to grow, three species predominate: cheatgrass, dandelion (*Taraxacum officinale*) and peppergrass (*Lepidium perfoliatum*). This vegetation occurs along highway shoulders, and on the site of old buildings about Casa Diablo Hot Springs proper. Crested wheatgrass (*Agropyron cristatum*) has been planted along roadcuts of the present-day alignment of Highway 395. Floristic elements of this habitat are the initial colonists of sites where revegetation has been attempted at Casa Diablo geothermal developments.

4.1.2 RARE PLANTS

No rare or endangered vascular plant species were observed on the study area during our survey. It should be noted that field work for this survey was conducted at a time of year when most potential sensitive plants species would have been dormant and consequently difficult to detect.

Our inspection of habitat features of the study area indicated that it is unlikely that sensitive plant species occur on the site. Since, however, knowledge of the flora of the region is still rudimentary, we can not make an unequivocal negative declaration that no rare plants occur on the site.

Based on the array of species and habitats of rare plants known for the eastern Sierra region (Table 2), we can offer two lines of evidence why we feel occurrence of specific species on the Casa Diablo Hot Springs study site would not be expected given current information.

History of Botanical Collecting - the site, located adjacent to a highway, has often been visited by botanists passing through the eastern Sierra region. The first collecting of which we are aware (through personal communications and herbarium research) was in the 1930's, when John Thomas Howell and Alice Eastwood, and Frank Peirson collected along Highway 395 and in the Mammoth Area. Eastwood and Howell visited Casa Diablo Hot Springs, but found no rare species there. The Eastwood and Howell collecting trips were effective explorations, as several previously unknown species were discovered (including *Lupinus duranii*, *Astragalus monoensis*, and *A. joahnnis-howellii*). Peirson's collecting in the Long Valley region was also thorough, for example, he discovered *Pedicularis crenulata* var. *candida* growing at Convict Creek.

Other botanists, including Dean Taylor and Mary Dedecker, have also collected at the site in the past, without noting rare plants.

Array of Habitats and Geography - the availability of habitats for rare plants on the site are seemingly such that potential habitat for several candidate species in Table 2 is absent. The Mono milkvetch (*Astragalus monoensis*) is known to occur about 1 mile to the north of the Casa Diablo area, but we did not observe this species on the study area. At the time of our survey, *A. monoensis* plants, although dormant, were evident and easily recognized (as observed at nearby populations), indicating that we would have detected any populations on the site. The habitat for this plant, sterile pumice soils with moderate to low sagebrush cover, occurs on the northern portion of the site, but *A. monoensis* is apparently absent there.

Others of the species listed in Table 2 are typical of hot springs or alkaline meadow areas in the Eastern Sierra. Occurrence of these species on the Casa Diablo Hot Springs site was not documented in this survey, nor have there been historical reports of these taxa from the site.

Two species occurring in the Mammoth region for which detailed habitat information is lacking, Mammoth Lupine (*Lupinus sublanatus*), last seen in 1935 and known only from the type collection, and Pine City stonecrop (*Sedum pinetorum*), last seen in 1913 and also known only from the type collection, are unlikely to occur on the site. The Mammoth Lupine is known from a single collection near the "Earthquake fault" along Highway 203, while the sedum was collected in the montane forests west of Old Mammoth (the sedum was once thought to occur only in Mexico, but this supposition is erroneous).

4.1.3 BOTANICALLY SENSITIVE AREAS

Figure 3 depicts the location of botanically sensitive habitats occurring on the Casa Diablo study site. Two habitats occurring in the study area can to be considered sensitive habitats (using California Department of Fish and Game, Data Base Criteria, cf. Holland 1986): Thermal marsh and Rhyolite Buckwheat scrub.

Thermal marsh vegetation occurs at the immediate outflow of Casa Diablo Hot Springs. In its present condition, this habitat type has been influenced by past recreational, commercial and geothermal activities. Portions of the marsh have been eliminated by filling and construction of a berm surrounding the largest marsh area.

The study area supports an unusual example of hydrothermal control of vegetation pattern and structure of significance. Several areas of unusual soils produced by intermittent hydrothermal activity occur on the eastern portion of the site, producing openings in otherwise forested terrain. These sites are characterized by the Rhyolite Buckwheat habitat-type. During the 1983 magmatic dome uplift in the Casa Diablo area, soil surface temperatures bordering these openings became sufficient to kill pinyon pines (anecdotal observations of a soil temperature of 145°F at 3 inches depth were made by BSAI botanist Dean Taylor at this site in July of 1983).

4.2 FAUNA

4.2.1 Aquatic Habitats

Aquatic habitats of the Casa Diablo Hot Springs study area are of limited size and extent. A thermal marsh area occurs at the outflow of the several hot springs proper.

The site also contains several brine ponds of geothermal powerplant effluent. The brine ponds have fluctuating water levels and are generally less than 1 acre in size. These ponds do not support emergent vegetation or riparian associated vegetation at this time, limiting their present value to wildlife.

A small stream about 2 to 6 feet in width transects the southwestern corner of the study area. Little riparian vegetation is associated with this stream, and no salmonid fishery is expected. Flow in this stream is derived from two sources: from artificial drainage of the former Casa Diablo Lake (situated 0.5 miles northwest of the hot springs) necessitated by highway alignments, and from discharge of the hot springs. Although the stream is tributary to Mammoth-Hot Creek, it is small and sufficiently ephemeral that it is unlikely that it supports a significant salmonid fishery.

4.2.2 Terrestrial Habitats

From a standpoint of providing wildlife habitat, the study area contains two principal habitats. Much of the site is dominated by pine forest, specifically Jeffrey Pine (*Pinus jeffreyi*), with singleleaf pinyon pine (*Pinus monophylla*) as an associated secondary species. The forested habitat is interspersed with sagebrush (*Artemisia tridentata*) shrub habitat. Flat areas of lower elevation at the south and west sides of the study area contain minor amounts of meadow vegetation. Occasional rock outcrops are associated with the ridgeline in the east half of the study area. Areas of geothermally altered soil can be found on the site where vegetation patterns are controlled thermal and chemical changes in the soil caused by hot spring activity. Herbaceous vegetation tolerant of the altered soil conditions has replaced the trees previously found on such site.

Cones of both pine species present provide seed for mammals and birds, an important food source for many animals. Nesting opportunities are provided in cavities and branches of the conifer species. The forest stands of the study area are relatively young, subjectively estimated at 40-80 years (based on diameter and site index of *P. jeffreyi* in the area, cf. Taylor 1980), and from 8-20 inches diameter. The density of snags on the site is low compared to the potential for these cover types (i.e. at nearby Indiana Summit Research Natural Area) and may represent a limiting factor for cavity dependent species. Snag density on the site is probably low due to past wildfire, and to woodcutting, but it also may be naturally lower in general as the study area is located in an area on the geographic boundary between sagebrush and forest. Dead and down woody materials are also relatively scarce (due principally to wood gathering), limiting foraging, denning, nesting, and "look-out" opportunities for some species of birds and mammals.

The northeast portion of the study area contains Jeffrey pine forest with north and northeast aspects. Greater basal area, higher snag density, greater canopy cover, and more dead and down woody materials are found in these stands. Understory vegetation dominated by tobacco bush (*Ceanothus velutinus*) and other mesophytic species relative to the sagebrush of the drier microsites are found. The tobacco bush provides a dense understory and ample forage opportunities for many favored wildlife taxa.

Several buildings, geothermal wells, many dirt and paved roads, power lines, and an electric substation are found on the site. These areas of substantially altered habitat are mostly devoid of vegetation and are of little or no value to wildlife. Because of its location, the site serves as a deer staging area during spring migration to higher elevation summer range (T. Kucera, personal communication, 1986). Proximity to several passes west of the site allow access to the western Sierra through passes well vegetated with forage. Migrating deer use winter range in the Owens Valley and Round Valley areas, several miles south.

4.2.3 Species Of Special Concern

Consultation with U. S. Forest Service biologists and literature review has identified a list of 8 Species of Special Concern that are potential users of the Casa Diablo Hot Springs study site as either migrants or residents. Species were selected because of their legal or management status, or as indicator species of a particular habitat type. These indicator species were selected to represent foraging guilds important in eastern Sierra ecosystems. For indicator species, it is assumed if habitat requirements for this species were met then the habitat requirements for other species using the same habitat would also be met (McCarthy and Hargis 1984).

Federally endangered species selected for discussion are: bald eagle (*Haliaeetus leucocephalus*) and peregrine falcon (*Falco peregrinus*). Fully protected species are: Northern goshawk (*Accipiter gentilis*), pygmy nuthatch (*Sitta pygmaea*), Williamson's sapsucker (*Sphyrapicus thyroideus*), and the hairy woodpecker (*Picoides villosus*). Commercially important species are mule deer (*Odocoileus hemionus*) and sage grouse (*Centrocercus urophasianus*).

Peregrine falcon (*Falco peregrinus*). The study area contains cliff faces 30-50 feet in height with very few if any ledges that would be suitable for nesting sites. The area is at least 5 miles from the nearest major river, lake, or marsh. Project time constraints did not allow for a quantitative prey base assessment. Disturbance, distance to open water, lack of suitable cliff habitat, and the high elevation of the site contribute to low suitability of this site for peregrines. Peregrines have been reintroduced in Mono county each year from 1982 to 1985 at a site approximately 22 miles away. A reintroduction of captive bred peregrines to a site 8 miles away is planned for 1987. Juvenile peregrines or wandering adults may visit the site looking for foraging opportunities.

Bald eagle (*Haliaeetus leucocephalus*). A bald eagle was observed from the project site soaring to the east at an estimated distance of around one mile. Bald eagles are known to winter in the Owens Valley and Lake Crowley areas approximately 8 miles south and east of the site, and at the June Lake area 10 miles north. Habitat at the Casa Diablo Hot Springs site is of low suitability for bald eagles for the following reasons: 1) early successional stage of Jeffrey pine cover type, 2) dominant conifers of less than 28" dbh, 3) less than 2 to 3 spike top or snag trees within one-quarter mile of suitable nest trees, 4) lack of fish and/or waterfowl as food supply, 5) greater than 1 mile to major river, lake, or marsh, and 6) frequent foot, vehicular, and industrial traffic within one-half mile of most of the site. Bald eagles may use the site occasionally as a migration or dispersion route.

Northern goshawk (*Accipiter gentilis*). The goshawk may be only an occasional visitor to the study area (C. McCarthy pers. comm. 1986). Goshawks are birds of mature forest characterized by a relatively closed overstory and a dense understory of seedlings of non-uniform height (Call 1978). The Jeffrey pine forest at the site is relatively young, with only a very sparse understory of occasional pinyon pine. The habitat within the Casa Diablo Hot Springs study area is judged to be largely unsuitable for goshawks.

Cavity nesting species: Pygmy nuthatch (*Sitta pygmaea*), hairy woodpecker (*Picoides villosus*), and Williamson's sapsucker (*Sphyrapicus thyroideus*). Parameters for optimum habitat for each of the above species is provided in Table 1 of McCarthy and Hargis (1984). Optimal habitat components for these species were developed for a timber compartment in the Mono Lake Ranger District, Inyo National Forest, located in the Glass Mountains approximately 10 miles east of the study site.

Based on the criteria of McCarthy and Hargis (1984), habitat within the Casa Diablo study area is inadequate for the Williamson's sapsucker due to lack of lodgepole pine cover type, stand basal area <38 m^2/ha, and fewer than 3.7 snags greater than 30 cm dbh per hectare.

Habitat on the study site is of secondary value for pygmy nuthatches and Hairy woodpeckers. The habitat parameters at the study site are within those suggested by McCarthy and Hargis (op. cit.) except for snag density. There are some areas on site of snag density meeting or exceeding those recommended. However, overall snag density does not provide optimum (primary) habitat, so that the forest habitat on the Casa Diablo study site can be characterized as of intermediate importance to this guild.

Sage grouse (*Centrocercus urophasianus*). Sage grouse are dependent on sagebrush stands for nesting, thermal and hiding cover, and feeding during fall and winter (Call and Maser 1985). Wet meadows and other grassland habitats are used for feeding when succulent vegetation and seeds are available. The interspersion of open grassland less than 275 m in circumference with areas of tall and short sagebrush with 20 to 40 percent canopy closure provides good sage grouse habitat for feeding, nesting, and breeding activity (Rogers 1964, Wallestad and Pyrah 1974, Klebenow 1969). The need for free water likely depends on the availability of succulent vegetation and the timing of the curing of herbaceous vegetation in the summer (Call and Maser 1985). The study area provides limited amounts of moderately suitable sage grouse habitat on the west, south, and central portions of the area. Most of the rest of the study area does not contain enough sagebrush cover type.

Pine Marten (*Martes americana*). Martens use red fir and lodgepole pine forests, alpine zones, talus, and open meadow habitat in the Sierra Nevada (Harris 1982). Dense coniferous forests provide cavities and down logs for denning and nesting and foraging opportunities among the upper branches (Ingles 1965). Cavities are limiting on the site and may not provide denning opportunities. Martens may use the denser stands of Jeffrey pine to the north area of the site for foraging. Forest stands on the Casa Diablo site may be used for travel to more suitable habitats in the Glass Mountain range to the east.

Mule deer (*Odocoileus hemionus*). The site must be evaluated as a staging area for deer migration as well as an area where deer feed and rest. Herds of deer winter in Long Valley, Little Round Valley, Round Valley, and the Owens Valley. In spring, deer move through the study site, crossing Highways 395 and 203, staging in the area for their migrations to the crest of the Sierra through either Deadman Pass, Mammoth Pass, at San Joaquin Mtn., Solitude Creek, Mammoth Rock, or at other sites west of the study area. Other staging areas in close proximity are located in the Sherwin Creek and Laurel Creek areas.

Habitat within the study site is of moderate value for mule deer. Thermal cover is of moderate value because crown closure is in general less than 75% in some of the study site. There is sufficient area (>0.8 ha) of shrubs of adequate height (>1.5 m) (Leckenby et al. 1982). Relative to the valley floor of low sagebrush and grassland habitat, the project area provides good thermal cover and will likely be favored in times of thermal stress (too hot or too cold).

Adequate hiding cover can be found throughout much of the site. Hiding cover may be defined as vegetation that hides 90% of a bedded deer from view at a distance of 45 meters or less (Thomas et al. 1979).

Mule deer will utilize grass, forbs, and browse plants for forage at different times of the year. Browse and cured grass were observed on site; and it can be safely assumed forbs are present during the spring and summer. No quantitative assessment can be made in this report of the adequacy of forage availability on the site. Cursory examination did not reveal a severely overbrowsed or overgrazed range, except in the southwestern portion of the site accessible to cattle. Deer utilization of bitterbrush on the site (as judged by leader use) was moderate.

Fawning habitat should have available a mix of thermal and hiding cover, open water, a canopy closure of at least 40%, and a slope less than 30%. Succulent vegetation should be readily available through June. On the site, marginal cover reduces suitability of the Casa Diablo geothermal site as fawning habitat. November field visits negate an analysis of the site's suitability for forage during the fawning period.

Figure 4 provides a map depicting concentrations of observed deer sign on the Casa Diablo Study site. The map is based only on observations conducted during November, 1986 but may nonetheless reflect to some degree actual deer use patterns on site. Deer trails observed on the site are generally long-lived features, accumulating over months or years of deer use. Therefore, concentrations of deer trails are likely to reflect actual movement routes through the area to a large degree. Lack of observed deer trails on portions of the study site should not be taken to indicate lower deer usage, as deer trails are probably not persistent features due to physiographic differences.

Of the two major habitat types on the study area, forested vegetation is of value to deer for escape and thermal cover. Sagebrush vegetation is of value principally for forage production and staging during migration. Segments of the eastern and northern portions of the site could be of importance to some animals as fawning habitat

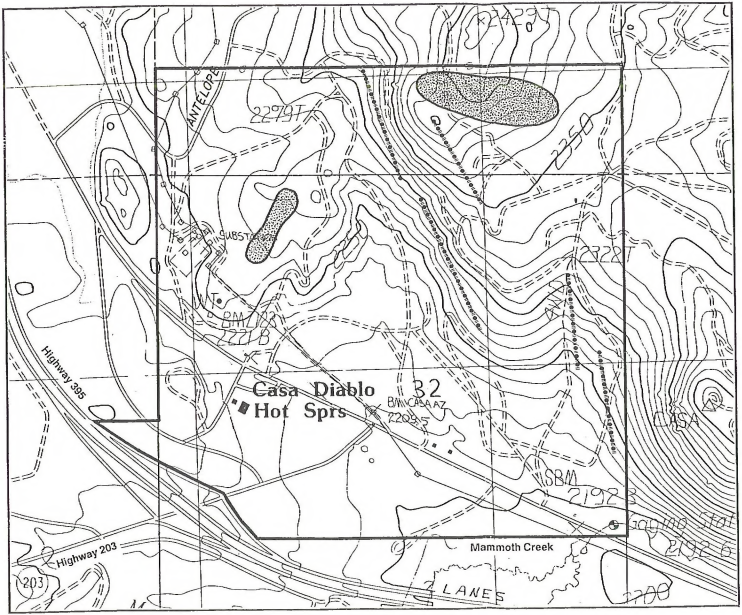

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Figure 4. Deer Observations

Deer Sign

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(Source: 1983 U.S.G.S. Old Mammoth Quadrangle)

5.0 DISCUSSION OF SITE BIOLOGICAL SENSITIVITIES

5.1 FLORA AND VEGETATION

Potential direct impacts to flora and vegetation include: direct removal of native vegetation due to construction activities, creation of ruderal and disturbed habitat for weeds, and direct impacts to sensitive habitats and possibly to sensitive plant species.

Construction and development activities at the Casa Diablo geothermal site could result in significant losses of native vegetation cover only if appropriate design, construction and rehabilitation measures are not strictly utilized.

Existing development of geothermal resources at Casa Diablo Hot Springs has resulted in several classes of impacts to vegetation. At present, the significance of these impacts are minimal to moderate. Development of additional generation facilities will require that planning, design and construction include measures to minimize potential impacts to vegetation, thus minimizing the possibility that vegetation impacts would reach a significant level (thus requiring mitigation).

At present, construction of well pads, pipelines, electrical transmission lines and roads have removed native vegetation from a small but noticeable proportion of the site. In many areas of past disturbance, habitat rehabilitation measures have been instituted, but have met with varying degrees of success. Jeffrey Pine saplings have been planted at several localities, with acceptable survival rates. Areas of soil disturbance have in some instances been recountoured, allowing for either natural revegetation or artificially aided revegetation. We observed that recent seeding to limit erosion has apparently been undertaken in some instances. Little actual establishment had occurred on these sites at the time of our visit, and we were unable to determine the elapsed time since these activities.

Natural successional patterns of vegetation in this region are relatively uniform and thus can be used to plan for and manage potential vegetation impacts associated with direct surface impacts. Within two growing seasons following clearing, cheatgrass stands usually becomes fully established. During this successional stage, significant cover of native annual herbs can develop, particularly where natural topsoil (and thus soil seedbanks) has been preserved. Often within 5 years following disturbance, shrubs have begun to establish. Rabbitbrush is usually the initial colonist, followed later by sagebrush and then bitterbrush and other shrubs. Conifer seedlings may not become naturally established until several decades following cessation of disturbance, as they have higher natural survivorship in dense shrub stands (where shrubs act as 'nurse-plants'). The shrub species common in the Casa Diablo study area have light, wind dispersed seeds. Thus, given several years, they should be expected to become naturally established on disturbed sites. Active revegetation efforts can incorporate introduction of shrub seed on to disturbed sites, thus facilitating and enhancing natural successional change.

Revegetation efforts in the Casa Diablo Hot Springs area will be complicated by edaphic controls on vegetation and successional patterns. In areas where the sterile and xeric deposits of hydrothermally altered substrates (ie. kalonitic clays and travertine) need revegetation, expensive and often only partially successful techniques utilizing fertilizing and irrigation may be necessary.

Limiting the degree and intensity of surface disturbance during construction and operation will reduce the need for active revegetation efforts. Pipelines traversing steep slopes should be avoided where possible. In the vicinity of the study area, slopes with grades greater than about 25% can become subject to erosion problems if appropriate construction and revegetation methodology is not utilized.

Active revegetation efforts on the Casa Diablo site should utilize techniques appropriate to arid, cold steppe sagebrush environments (i.e., methods appropriate to the Great Basin-Intermountain region). Planting of grass to establish cover should utilize species native to the site, such as Great Basin wildrye, rather than employing exotic, non-native taxa. Conifers planted on site should be limited to locally collected seed for maximum likelihood of success.

Operation and management of the site as an energy development can be compatible with maintenance of natural habitat values if careful planning and supervision is exercised. It is recommended that a qualified botanist and landscape architect be utilized in the planning and design process.

A significant detrimental impact to the Casa Diablo site has resulted from historic uncontrolled grazing. We recommend that consideration be given to the grazing management for the site. Reduction of overgrazing would help improve vegetation conditions on the developed portion of the site, thereby minimizing the potential significance of vegetation losses associated with project construction becoming significant. Grazing management would serve to compensate for disturbance to native vegetation that invariably will be associated with future energy development of the site. We would recommend that a grazing management plan be formulated for the site.

Ancillary Vegetation Impacts - presently, the study area is subject to a variety of threats to vegetation which are essentially an indirect product of development. Roads accessing the site are unrestricted, allowing travel at will. Much of the road network on the site is probably unnecessary for access to the site for operational purposes. The density of roads on the site has resulted in loss of vegetation due to vehicular traffic. Easy access to the site has also allowed significant impacts resulting from woodcutting.

Woodcutting in the past three years has resulted in removal of trees killed by the recent series of incipient volcanic events caused by a upwelling within the magma chamber underlying the Long Valley caldera. Illegal felling of standing, dead pinyon and Jeffrey pines is largely related to ease of access to the site.

Since our survey did not locate rare or sensitive plants on the study area, no recommendations are given to consider regarding impacts to rare plants.

Past activity associated with geothermal activity has resulted in loss of sensitive habitats from the site. The thermal marsh area surrounding the outflow to Casa Diablo Hot Springs has been influenced to varying degrees by filling and diking. It is our recommendation that these areas be avoided in future construction, and that consideration be given to removal of the dike surrounding the marsh area. Removal of the proposed well pads from the southern margin of the marsh is seemingly not feasible, but we do recommend no further encroachment on the marsh area.

Placement of roads and small well pads within the Rhyolite Buckwheat scrub areas has resulted in modification or elimination of a small proportion of this habitat from the site. We recommend that no additional roads, well pads or other construction requiring surface soil disturbance be proposed for this habitat. We also recommend that existing roads to well pads within this sensitive habitat type be closed to all vehicle traffic.

5.2 WILDLIFE

Possible construction and operational impacts to wildlife include: loss of native habitat to roads, buildings, pipelines, and well pads; disturbance to wildlife at various stages of its life cycle but especially nesting; the construction of utility transmission lines; vehicle traffic, and the possible disruption of deer from their regular migration routes.

The Mammoth Lakes area is expected to support new development in the recreation and geothermal industries and grow in population over the next several years. The cumulative effects of the proposed developments on wildlife habitats and populations will be much greater than the impacts being discussed here. Though evaluating the kinds and amounts of impacts that will occur as a result of expected developments are not within the scope of this biotic assessment, they require mention. It becomes especially critical in considering the effects this project may have on deer migration patterns.

This discussion assumes that most of the proposed construction will take place in the Jeffrey pine forest of the northwestern portion of the site, and on the sagebrush flats of the western portion of the project area. Minor amounts of forest land will be affected by the placement of well pads. A proposed pad (Well pad MP 22A-32) will occupy a sagebrush flat midslope above the present powerplant, displacing wildlife use from that particular stand of sagebrush. The juxtaposition of this stand surrounded by Jeffrey pine forest creates an area of higher biological diversity relative to the surrounding habitat. Habitat edge is created, providing foraging opportunities in close proximity to thermal and hiding cover. This particular site is evidently an area heavily used by deer, as judged by density of pellet-groups and severity of browsing of bitterbrush.

Animals that would be expected to be most affected by habitat losses are those restricted to particular habitats, microhabitats, or small home ranges, such as smaller mammals. Most of the wildlife species in the areas of construction will avoid direct losses by moving to adjacent similar or suboptimal habitat. Overcrowding and competitive exclusion in those areas could result in mortality to many displaced individuals. Any net loss of habitat would result in a proportional decrease in overall carrying capacity and associated wildlife populations.

Loss could be compounded for wildlife species whose reproductive periods coincide with construction, if nesting and nursery areas are destroyed and disturbed. Such a potential impact would be highest in the spring and summer months.

Pipelines to carry hot water from the well pads to the powerplants will cross through Jeffrey pine and sagebrush habitat. If the pipelines are too low to the ground at their lowest point, or too high above the ground at their highest point, they may provide a physical barrier to movement by wildlife.

Significant edge can be created when a narrow strip of vegetation is cleared or altered to an earlier successional stage for powerline or pipeline right-of-

-ways. This edge effect often increases biological diversity within otherwise structurally simple habitats. Pipeline distances of less than one-half mile and right-of-ways following roads would minimize this beneficial effect.

The operation of the well pads and especially the powerplants will generate constant, loud, high frequency noise. Little is known about the effects of loud noise on wildlife. It should be assumed, however, that loud and lingering noise can disrupt some wildlife life cycle patterns and could produce organic hearing deficits with continuous exposure. For deer, noise is often not associated with exclusion from an area, as the animals may habituate.

Increased vehicle traffic associated with construction and operation of the well pads and powerplant will increase the likelihood of wildlife losses due to collisions with cars and trucks.

Well pads and pipelines carrying hot water can rupture and leak in the event of an equipment failure. Hot water of several hundred degrees would be fatal to any animal that came in direct contact with the water or steam. Hot water running down a slope or pooling would drown any nests or burrows under the water, and increase the temperature of any burrows or ground nests in the area. An accident of this type, however improbable from an engineering standpoint, may not prove fatal to affected wildlife but at very least will provide a disruption to the life cycle of the affected animals.

5.2.1 Potential Specific Wildlife Impacts

Peregrine falcon. Conversion of natural areas to energy development may reduce the area's potential for foraging habitat. Reintroduced peregrine falcons may use the area for occasional foraging and as dispersal routes for juveniles. However, the lack of open water on the site and the relative scarcity of waterfowl, columbids, and other favored avian prey species minimizes the potential impacts of this project on foraging habitat. However, future development off-site in the wet meadows and marshes to the south may reduce the value of those habitats for foraging. In the aggregate, there may be a greater future impacts related to increased development and population in the Mammoth-Long Valley area. Geothermal development at Casa Diablo Hot Springs is incrementally part of this aggregate potential impact. Impacts on breeding of peregrines will be low due to the relative suitability of the area for peregrine falcon nesting habitat, however.

Bald eagle. Habitat at the project site is of low suitability for bald eagles. Habitat losses as a result of this project are expected to have low impact on the eagle. Bald eagles may have made greater use of the site in past years prior to the draining of Casa Diablo Lake.

Design of electrical transmission lines for future projects in the Casa Diablo area should incorporate methodology to avoid the potential for raptor electrocutions. Design specifications for implementations of raptor protection measures should be undertaken in conjunction with a qualified raptor biologist.

Sage grouse. Loss of sagebrush habitat to development can reduce the available nesting, wintering, and roosting habitat. The presence of human disturbances at the site may interfere with downslope movement to foraging habitat in the wet meadows of the valley. If leks are present near the site human disturbance may disrupt breeding and courtship activities. Further development in the region may reduce available habitat. Overall impacts to sage grouse may be moderate. Our survey of the study area indicates that the site is probably not used by sage grouse, due to past and present levels of human activity. Specifically, heavy vehicle traffic along Highways 395 and 203 would likely be sufficient to exclude sage grouse from the meadows near their junction. Additionally, these same meadows are heavily grazed and in poor range condition, a situation also not conducive to persistance of grouse populations.

Northern goshawk. Construction of well pads and buildings in sagebrush habitat should not have an impact on goshawks in the region. Construction activity in the Jeffrey pine forests on the site should not have an immediate impact on the goshawk due to the unsuitability of the habitat for goshawks given the present successional stage of forest development in the vicinity. The loss of Jeffrey pine forest to construction and development may have an impact in the future as the potential for mature forest with a well developed understory is lost. Overall impacts are expected to be slight.

Williamson's sapsucker. Habitat is not suitable for the Williamson's sapsucker. Any sighting on the site would be regarded as an accidental observation. Overall impacts of the project on this species can expected to be slight.

Pygmy nuthatch. Loss of forested habitat will reduce the number of available cavities for use by cavity dependent species. This project may affect small amounts of forest land which is suitable habitat for the pygmy nuthatch. However, the loss of any forest land will delay development of mature forest structure, possibly impacting the pygmy nuthatch guild. Disturbance by construction activities may disrupt birds attempting to nest. Overall impacts can be expected to be slight.

Hairy woodpecker. Any loss of forested habitat would reduce the number of available cavities for use by this and other cavity dependent species. The projects proposed for the site may affect small amounts of forest land. At present, forests at the site are suitable habitat for hairy woodpeckers. However, any loss of potential mature forest land typified by high snag densities would impact this species. Disturbance by construction activities may disrupt birds attempting to nest. Overall, impacts can be expected to be slight.

Pine Marten. Martens are not tolerant of human encroachment and disturbance. Though not common, most marten sightings are in isolated areas far from human presence. Construction and operation of well sites and geothermal plants would most likely preclude the marten from using areas within a close radius of the activity. The status of the marten in this region is uncertain, but operation of this project could affect movement patterns of this species. Loss of forested habitat reduces the availability of favored tall trees for the arboreal activities of this mammal. This site does not constitute favored habitat for this species. Overall impacts could be expected to be slight.

Mule deer. Construction of roads, well pads, and buildings on the site most likely will affect staging areas for the spring migration of mule deer of the Sherwin-Buttermilk deer herd. An estimated 3,000 to 4,000 deer stage within 5 miles of the site before migrating. Loss of sagebrush habitat used extensively during spring would reduce available forage and cover. Loss of the conifer forest and sagebrush edge would further reduce forage that is in close proximity to thermal cover. Increased activity at the construction site may increase the chances of deer being struck by vehicles and may disturb deer as they await spring thaw in the passes. Loss of forested habitat would reduce available thermal and hiding cover on the site. Cumulative effects of geothermal, industrial, and residential development in the Mammoth Lakes area have the potential to seriously alter deer migration patterns for the herds in the area. The proposed Sherwin ski area might place construction activity and habitat loss in the Solitude Creek migration corridor, used by many of the deer that stage in this project site. Further study is needed to fully appreciate the effect this project and others in the area will have on the deer herds. Overall cumulative impacts to deer could be expected to be moderate to high without appropriate mitigation. Careful consideration should be given to siting the power plant in a site that does not interfere with normal deer yarding and migration patterns. At least the eastern and northern portions of the study site appear to be heavily used by deer relative to the surrounding area, and consequently requires careful evaluation in planning location of facilities, roads and pipelines.

Control of ancillary disturbance levels on the site, such as from unrestricted vehicle traffic, woodcutting etc. would serve to reduce the aggregate wildlife impacts of energy development in the project vicinity.

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APPENDIX 1
PLANT SPECIES LIST

Checklist of Vascular Plants
Observed at Casa Diablo Hot Springs, Mono County, California

25-26 November, 1986

Apiaceae
- *Pteryxia terebinthina*

Asteraceae
- *Artemisia cana* ssp. *bolanderi*
- *Artemisia nova*
- *Artemisia tridentata* ssp. *vaseyana*
- *Chaenactis douglasii*
- *Chrysothamnus nauseosus* ssp. *albicaulis*
- *Cirsium drummondii*
- *Conyza canadensis*
- *Haplopappus bloomeri*
- *Lepidium perfoliatum*
- *Lygodesmia spinosa*
- *Machaeranthera canescens*
- *Taraxacum officionale*
- *Tetradymia cansecens*
- *Wyethia mollis*

Boraginaceae
- *Amsinckia tesellata*
- *Cryptantha confertiflora*

Brassicaceae
- *Caulanthus pilosus*
- *Descurania californica*
- *Lepidium virginicum*
- *Rorippa nasturtium-aquaticum*
- *Sisymbrium altissimum*
- *Streptanthus tortuosus* var. *orbiculatus*

Chenopodiaceae
- *Salsola australis*

Cupressaceae
- *Juniperus occidentalis* var. *australis*

Cyperaceae
- *Carex douglasii*
- *Carex nebrascensis*
- *Carex rossii*
- *Eleocharis acicularis*
- *Eleocharis palustris*
- *Scirpus americanus*
- *Scirpus nevadensis*

Fabaceae
    Astragalus purshii var. *lectulus*
    Lupinus caudatus

Gentianaceae
    Frasera puberulenta

Geraniaceae
    Erodium cicutarium

Iridaceae
    Iris missouriensis

Juncaceae
    Juncus balticus

Lemnaceae
    Lemna minima

Liliaceae
    Calochortus sp. (cf. *leichtlinii, bruneaunis*)
    Fritillaria pinetorum

Loranthaceae
    Phorodendron juniperinum

Onagraceae
    Oenothera xylocarpa

Papaveraceae
    Argemone munita ssp. *rotundata*

Poaceae
    Agrostis exarata
    Agropyron cristatum
    Agropyron trachycaulum
    Bromus tectorum
    Distichilis spicata var. *stricta*
    Elymus cinereus
    Hordeum jubatum
    Muhlenbergia asperifolia
    Oryzopsis hymenoides
    Poa juncifolia
    Poa pratensis
    Polypogon monspeliensis
    Puccinellia lemmonii
    Sitanion hystrix
    Stipa comata
    Stipa speciosa

Polemoniaceae
Eriastrum wilcoxii
Gilia sp. (annual)
Leptodactylon pungens ssp. *pulchriflorum*
Linanthastrum pachyphyllus

Polygonaceae
Eriogonum baileyi
Eriogonum kennedyi var. *purpursii*
Eriogonum umbellatum var. *dichrocephalum*
Polygonum aviculare
Rumex crispus

Portulacaceae
Lewisia rediviva

Pinaceae
Pinus jeffreyi
Pinus monophylla

Ranunculaceae
Ranunculus aquatilis
Ranunculus cymbalaria var. *saximontana*

Rhamnaceae
Ceanothus velutinus

Rosaceae
Amelanchier utahensis
Holodiscus microphyllus
Potentilla biennis
Prunus andersonii
Purshia tridentata
Rosa woodsii var. *ultramontana*

Rupiaceae
Ruppia marina

Salicaceae
Salix exigua
Salix lutea

Scrophulariaceae
Castilleja applegatei
Mimulus coccineus
Mimulus guttatus
Penstemon speciosus
Verbascum thapsus

Solanaceae
Nicotiana attenuata

July 6, 1988
BioSystems Analysis, Inc.

SCOPE-OF-WORK

Casa Diablo Geothermal Biological Studies

BioSystems Analysis, Inc. will conduct a field biological inventory of the 280-acre Casa Diablo geothermal site, Mono County, California. The purpose of the inventory is to provide base-line data on vegetation, rare plants, birds and small mammals. Inventory methods will be systematic and quantitative, facilitating re-sampling to assess the nature of any post-project impacts.

1. Rare Plant Surveys

The entire study area will be surveyed for rare, endangered or sensitive plants. Emphasis will be placed on floristic characterization of those habitats most likely to support rare plant populations. Species considered for survey will include: 1) species listed under the Endangered Species Act of 1973 (as amended); 2) Federal candidate species and BLM sensitive species; 3) U.S.Forest Service sensitive species; 4) species on List 1B, List 2 or List 3 or List 4 of the California Native Plant Society Inventory. Table 1 enumerates species with the potential to occur in the vicinity of the Study Area (based on known geographic range and habitat requirements).

Methodology of the survey will follow Nelson (1987) and California Department of Fish and Game, Nongame Heritage Program (1984) guidelines. Using these methods, the entire flora of the site is inventoried. All plant species encountered along roving "meander-transects" by botanists on foot are noted. Survey of the site will be conducted between June and August, 1988.

2. Fumarole Vegetation Characterization

BioSystems botanists will conduct focused, quantitative vegetation inventory of selected fumarole areas (Figure 1). Three types of information will be provided for each fumarole site: 1) quantitative vegetation characterization; 2) detailed vegetation map; 3) photographic characterization. At each site characterized, grid-lines will be established. Grid size will be adjusted to accommodate the size of the site, and will range from approximately 1 by 1 meter to 10 by 10 meters. Location to nearby landmarks will be recorded for relocation. Where necessary, permanent stakes will be installed to facilitate relocation of the grid.

Table 1. Rare plants potentially occurring in the Casa Diablo Hot Springs region.

Species (1)	U.S.F.S. Status (2)	U.S.F.W.S. Listing (3)	State Status (4)	CNPS Status (5)	Habitat Type (6)	Substrate (7)	Elevation Range (8)	Known Distribution (9)	Flowering Period (10)
Astragalus monoensis Mono milkvetch	Sensitive	Category 1	Rare	2-2-3 List 1B	Sagebrush flats	pumice soils	6700-11,000	Mono	May-July
Astragalus johannis-howellii Howell's locoweed	None	Category 3C	Rare	2-2-2 List 1B	Sagebrush scrub	travertine or rhyolite	7000,8000	Mono [NV]	May-July
Astragalus lentiginosus var. piscensis / Fish Slough milkvetch	None	Category 1	None	3-2-3 List 1	Alkali sink	pH > 8.5	ca. 5000	Mono	July
Centaurium namophilum Nevada Centuray	None	None	None	1-1-3 List 4	Alkali sink	springs and seeps	above 4000	Mono, Inyo [NV, OR]	April-July
Eriogonum ampullaceum Mono Buckwheat	Sensitive	Category 2	None	2-2-3 List 1B	Sagebrush scrub and meadow borders	alkaline soils	5500-7500	Mono [NV]	May-July
Fimbristylis spadicea Hot Spring Sedge	None	Category 3c	None	2-2-1 List 2	Alkali sink	hot springs	2500-5500	Inyo, Mono, San Bernardino	April-June
Lupinus duranii Mono Lake lupine	None	Category 2	None	1-1-3 List 4	Sagebrush scrub & Jeffrey Pine	pumice soils	6500-9500	Mono	May-July
Lupinus montigenus Pumice Bush Lupine	None	None	None	None App. 1	Jeffrey Pine & Sagebrush	snowbanks	6000-10,000	Mono, Inyo [NV]	May-August
Lupinus sublanatus Mammoth Lupine	None	None	None	1-1-3 List 3	Jeffrey Pine	unknown	ca. 8000	Mono	July?

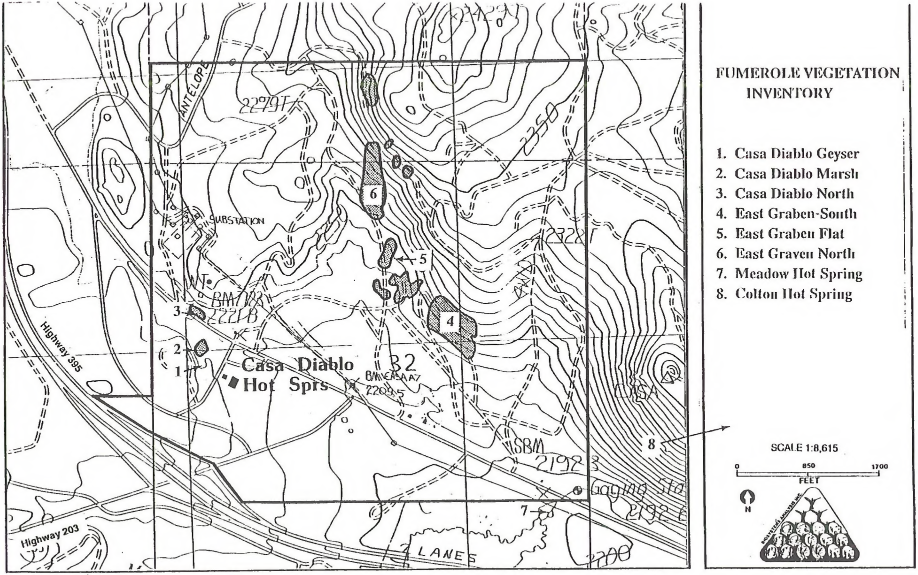
Table 1 (continued).

Species (1)	U.S.F.S. Status (2)	U.S.F.W.S. Listing (3)	State Status (4)	CNPS Status (5)	Habitat Type (6)	Substrate (7)	Elevation Range (8)	Known Distribution (9)	Flowering (10)
Pedicularis crenulata var. candida / Scolloped Lousewort	Sensitive	None	None	3-1-1 List 2	meadows	organic soils	ca. 7500	Mono [to Rocky Mountains]	June-August
Sedum pinetorum Pine City Stonecrop	None	Category 2	None	None App.1	pine forest	"in the duff"	ca. 8500-9500?	Mono	July?
Sidalcea covillei Owens Valley checkermallow	None	Category 2	Endg.	2-2-3 List 1B	Alkali sink	meaodw borders	4000-5500	Inyo	May-July

NOTES:

1. Nomenclature for scientific names and common names follows Smith and York (1984).
2. U.S. Forest Service management status (Region 5, Forest Service Manual, Title 2600).
3. Notice of Intent (50 CFR Part 17, Federal Register Vol. 50, No. 188, 27 September 1985).
   Federal Status designations are as follows:
   Category 1 = currently under review with extisting information sufficient to support listing as endangered or threatened.
   Category 2 = currently under review with extisting information insufficient to support listing.
   Category 3c = currently not under review, as taxon is more common than formerly thought.

4. California Department of Fish and Game, Designated Endangered or Rare Plants (26 March 1985)
5. Smith and York (1984). CNPS Listr 1B = Plants rare or endangered in California and elsewhere.
   List 2 = plants rare in California but more common elsewhere. List 3 = plants needing more information;
   List 4 = plants rare but not endangered in California. The R-E-D Code (Rarity-Endangerment-Distribution)
6. Based on Dedecker (1984) and field observations.
7. Based on field observations.
9. CNDDB records and Munz (1959, 1968).
10. Field observations.



FUMEROLE VEGETATION INVENTORY
1. Casa Diablo Geyser
2. Casa Diablo Marsh
3. Casa Diablo North
4. East Graben-South
5. East Graben Flat
6. East Graven North
7. Meadow Hot Spring
8. Colton Hot Spring
SCALE 1:8,615
0
850
1700
FEET
N
Casa Diablo Hot Sprs
32
ANTELOPE
SUBSTATION
2279T
2350
2322T
2221B
BM 2209.5
BM 2192.3
Gauging Sta
2200
CASA
LANES
Highway 395
Highway 203
1
2
3
4
5
6
7
8

(Source: 1983 U.S.G.S. Old Mammoth Quadrangle)

Quantitative vegetation characterization of each site will be accomplished by quadrat sampling. Quadrat sampling protocol will follow standard synecological vegetation inventory methods (Mueller-Dombois and Ellenberg 1974). Quadrat size will be adjusted to suit the size of a particular area under study, but in all cases will range from 0.2 dm by 0.5 dm to 1 by 1 m.

Data will be summarized in summary tables and graphics. Raw data from each sampling site will be provided in both hard-copy and electronic form (any MS-DOS format).

3. Breeding Bird Census. A combination of circular plots and linear transects will be used to determine the composition and relative abundance of the avifauna present on site. Five circular plot centers will be established in representative areas of the habitats present on site: pinyon-juniper woodland, Jeffrey pine forest, Jeffrey pine-pinyon pine forest, sagebrush scrub, and a Nebraska sedge meadow-Jeffrey pine forest-sagebrush scrub ecotone. In addition, data will be collected along linear transects established between the circular plot centers. Species, number of birds, sex, activity, method of detection, distance and azimuth, and time were recorded for each sighting.

Sampling will take place for five consecutive days during the breeding season. Each plot will be sampled twice daily; within one hour of sunrise and within one hour of sunset. Data analysis will provide information on species occurrence, relative density, and relative abundance. Plot centers will be marked with permanent posts so that the identical sites may be sampled during and after construction. The data will be useful in comparing any changes in composition, density, or abundance before and after construction.

4. Small mammal trapping. Baseline data on the small mammal community composition will be collected during 4 consecutive nights of live-trapping. Traps will be placed in representative areas of the major habitat types in approximate proportion to the amount of that habitat on site. In addition to the major habitat types mentioned above, traps will be also be placed in unique or potentially critical habitat areas: rhyolite buckwheat scrub (East Graben); hydrothermally altered areas (Casa Diablo marsh, Meadow Hot spring, and Colton hot spring). Traps will also be placed at the sites of the MP-1 and PLES-1 powerplants.

Traps will be set and baited at dusk and checked at dawn. They will remain closed during the day to avoid heat stress to any animal. Species, sex, physical condition, breeding condition, and trap location will be recorded. Locations and diagrams of the trapping grids or transects will be mapped so that they may be duplicated during or after construction. Trapping results will be analyzed for species composition and relative abundance.

x.x Rare Plant Survey

x.1 INFORMATION REVIEW

Selection of methodology appropriate for conducting a rare plant survey of the study area was made after consultation with U.S.F.S personnel (Christina Hargis, Inyo National Forest, pers. communication). Field work was conducted under the guidelines of the California Department of Fish and Game (1984), and those of Nelson (1984, 1987).

Species targeted for survey were those identified by Taylor and Buckberg (1986) via: 1] review of published and unpublished literature, including relevant environmental documents from the vicinity of the study region; 2] information from the Natural Diversity Data Base of the Natural Heritage Section, California Department of Fish and Game (Shevock and Hennessy 1987); and 3] communication with botanists with expertise with the local flora or particular taxonomic groups. Since the information assembled by Taylor and Buckberg (1986) considered current, no new data source review was conducted for the 1988 surveys.

Table 1 provides an enumeration of those rare plants with the potential to occur in the study area - basically any plants listed or considered for listing as rare, threatened, sensitive, or endangered by: *1)* the U.S. Fish and Wildlife Service (50 CFR Part 17, USFWS 1985) under the Endangered Species Act of 1973, as amended; *2)* the U.S. Forest Service (USFS 1984, cf. Smith 1987); *3)* the Bureau of Land Management (those taxa listed in USFWS 1985, cf. Hastey 1987); *4)* the California Fish and Game Commission under both the Native Plant Protection Act (Chapter 10, Section 1900, Fish and Game Code, Cochrane 1987) and the California Endangered Species Act (Sections 2050-2098, Fish and Game Code) or species that qualify for listing under the California Environmental Quality Act (Section 15380); *5)*; the California Native Plant Society (Smith and York 1984).

x.2 FIELD METHODS

Table 1 presents status, habitat, and distributional information for 12 CNPS rare or endangered plants with potential to occur in the vicinity of Casa Diablo Hot Springs. This table presents a refined working list for field surveys, based upon the data review described above. Known populations of many of these species in the eastern Sierra region were visited during the course of our surveys to ascertain phenology and microsite requirements for particular taxa.

Rare plant surveys were conducted on 7 June 1986 and again on 29-30 June 1988. All potential habitat for the 12 potential rare plants listed in Table 1 was visited. Field survey of the study area used the meander method of Nelson (1987). Two botanists walked in a meandering fashion through the survey area, recording each plant species encountered. The surveys were conducted at the peak of the growing and flowering season for the area, at the appropriate stage of phenology to identify any plant species encountered.

Table 1. Rare plants potentially occurring in the Casa Diablo Hot Springs region.

Species (1)	U.S.F.S. Status (2)	U.S.F.W.S. Listing (3)	State Status (4)	CNPS Status (5)	Habitat Type (6)	Substrate (7)	Elevation Range (8)	Known Distribution (9)	Flowering Period (10)
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Astragalus johannis-howellii Howell's locoweed	None	Category 3C	Rare	2-2-2 List 1B	Sagebrush scrub	travertine or rhyolite	7000,8000	Mono [NV]	May-July
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Lupinus sublanatus Mammoth Lupine	None	None	None	1-1-3 List 3	Jeffrey Pine	unknown	ca. 8000	Mono	July?

Table 1 (continued).

Species (1)	U.S.F.S. Status (2)	U.S.F.W.S. Listing (3)	State Status (4)	CNPS Status (5)	Habitat Type (6)	Substrate (7)	Elevation Range (8)	Known Distribution (9)	Flowering (10)
Pedicularis crenulata var. candida / Scolloped Lousewort	Sensitive	None	None	3-1-1 List 2	meadows	organic soils	ca. 7500	Mono [to Rocky Mountains]	June-August
Sedum pinetorum Pine City Stonecrop	None	Category 2	None	None App.1	pine forest	"in the duff"	ca. 8500-9500?	Mono	July?
Sidalcea covillei Owens Valley checkermallow	None	Category 2	Endg.	2-2-3 List 1B	Alkali sink	meaodw borders	4000-5500	Inyo	May-July

NOTES:

1. Nomenclature for scientific names and common names follows Smith and York (1984).
2. U.S. Forest Service management status (Region 5, Forest Service Manual, Title 2600).
3. Notice of Intent (50 CFR Part 17, Federal Register Vol. 50, No. 188, 27 September 1985).
   Federal Status designations are as follows:
   Category 1 = currently under review with extisting information sufficient to support listing as endangered or threatened.
   Category 2 = currently under review with extisting information insufficient to support listing.
   Category 3c = currently not under review, as taxon is more common than formerly thought.

4. California Department of Fish and Game, Designated Endangered or Rare Plants (26 March 1985)
5. Smith and York (1984). CNPS Listr 1B = Plants rare or endangered in California and elsewhere.
   List 2 = plants rare in California but more common elsewhere. List 3 = plants needing more information;
   List 4 = plants rare but not endangered in California. The R-E-D Code (Rarity-Endangerment-Distribution)
6. Based on Dedecker (1984) and field observations.
7. Based on field observations.
9. CNDDB records and Munz (1959, 1968).
10. Field observations.

x.x Results

x.1 RARE PLANTS

No rare or endangered vascular plant species were observed on the study area during our survey. Inspection of habitat features of the site confirmed our previous assumption (Taylor and Buckberg 1986) that sensitive plant populations were not likely for the Casa Diablo Hot Springs site, based on 1) habitat features, and 2) a long history of local plant collection along Highway 395 in the general region.

Appendix A provides a list of vascular plant species observed on the study site. A comparison with the species list compiled during our previous survey, conducted in the winter of 1986, indicates a considerably more diverse flora for the Casa Diablo Hot Springs site. In 1986, 90 taxa of vascular plants were seen. Our surveys during the summer of 1988 added 66 plant taxa to the species list, for a total of 166 taxa comprising 40 families of vascular plants. The majority of additions to the species list were plants growing in meadow vegetation along Mammoth Creek, and in the outflow marshes from Casa Diablo Hot Spring, Meadow Hot Spring and Colton Hot Spring. Relatively few species occurring in upland habitats (i.e., Jeffrey Pine Forest or hydrothermally altered areas) went undetected in our previous survey.

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July 12, 1988

Checklist of Vascular Plants Observed at Casa Diablo Hot Springs, Mono County, California

Dean Wm. Taylor & Glenn L. Clifton
BioSystems Analysis, Inc.

This checklist covers the general vicinity of Casa Diablo Hot Springs, including a 620 acre area surveyed in 1986 (Taylor and Buckberg 1986), and a smaller (±280 acres) surveyed in the summer, 1988. The list is is based on four visits: 25-26 November, 1986; 30 April 1987; 7 June 1988 and 29 June 1988. Nomenclature generally corresonds to Munz and Keck (1959), except where superceeded by more recent monographic treatment for a given taxon, or by the appropriate edition of the Intermountain Flora (Cronquist et al. 1972, 1977, 1985). This list corrects several epithets applied to dried remains of plants observed during a winter visit in 1986 (November 25-26).

Alliaceae
- *Muilla transmontana* Greene

Apiaceae
- *Pteryxia terebinthina* (Hooker) Coulter & Rose var. *californica* (Coulter & Rose) Mathias

Asteraceae
- *Achillea millefolium* L. var. *borealis* (Bong) Farw.
- *Anisocoma acaulis* Torrey & Gray
- *Artemisia cana* Pursh ssp. *bolanderi* (Gray) G.H. Ward
- *Artemisia ludoviciana* Nuttall ssp. *ludoviciana*
- *Artemisia nova* A. Nelson
- *Artemisia tridentata* Nuttall ssp. *vaseyana* (Rydberg) Beetle
- *Chaenactis douglasii* (Hooker) Hooker & Arnott var. *rubricaulis* (Rydb.) Ferris
- *Chrysothamnus nauseosus* (Pallas) Britton ssp. *albicaulis* (Nuttall) Hall & Clements
- *Cirsium drummondii* Torrey & Gray
- *Conyza canadensis* L.
- *Ericameria bloomeri* (Hooker) J.F. MacBride var. *bloomeri*
- *Erigeron divergens* Torrey & Gray
- *Erigeron loncophyllus* Hooker var. *loncophyllus*
- *Layia glandulosa* (Hooker) Hooker & Arnott
- *Machaeranthera canescens* (Pursh) Gray ssp. *cansecens*
- *Malacothrix clevlandii* Gray
- *Pyrrocoma lanceolatus* (Hooker) Greene
- *Senecio vulgaris* L.
- *Stephanomeria spinosa* (Nuttall) S. Tomb
- *Taraxacum officionale* L.
- *Tetradymia cansecens* DC.
- *Wyethia mollis* Gray

Betulaceae
  Alnus incana (L.) Moenc. ssp. *tenuifolia* (Nuttall) Breitung

Boraginaceae
  Amsinckia tesellata Gray
  Greeneocharis circumscissa (Hooker & Arnott) Rydberg var. *hispdiula* (MacBride)
  Lappula redwoskii (Hornem.) Greene
  Oreocarya confertiflora Greene
  Plagiobothrys kingii (Watson) Gray var. *harkensii* (Greene) Jepson
  Tiquilia plicata (Torrey) A. Richards

Brassicaceae
  Caulanthus pilosus Watson
  Descurania californica (Gray) O.E. Schultz
  Descurania sophia (L.) Webb. ex. Prantl.
  Lepidium perfoliatum L.
  Lepidium virginicum L. var. *pubescens* (Greene) C.L. Hitchcock
  Nasturtium officionale R. Br.
  Rorippa teres (Michaux) R. Stuckey
  Sisymbrium altissimum L.
  Streptanthus tortuosus Kellogg var. *orbiculatus* (Greene) Hall

Caryophyllaceae
  Cerastium vulgatum L.
  Stellaria longipes Goldie

Chenopodiaceae
  Salsola iberica Sennen & Pau

Cupressaceae
  Juniperus occidentalis Hooker ssp. *australis* Vasek

Cyperaceae
  Carex athrostachya Olney
  Carex aquatilis Wahlenb.
  Carex douglasii Boott
  Carex nebrascensis Dewey
  Carex rossii Boott ex Hooker
  Carex simulata Mackenzie
  Eleocharis acicularis (L.) Roemer & Schultes
  Eleocharis bolanderi Gray
  Eleocharis palustris (L.) Roemer & Schultes
  Scirpus americanus Pers.
  Scirpus nevadensis Watson

Equisetaceae
  Equisetum arvense L.
  Equisetum laevigatum A. Braun

Fabaceae
- *Astragalus purshii* Douglas ex Hooker var. *lectulus* (Watson) Jones
- *Lupinus caudatus* Kellogg
- *Lupinus polyphyllus* Lindley ssp. *superbus* (Heller) Munz
- *Lupinus sellulus* Kellogg ssp. *sellulus*
- *Trifolium longipes* Nuttall
- *Trifolium wormskjoldii* Lehm.
- *Trifolium repens* L.

Gentianaceae
- *Frasera puberulenta* A. Davidson

Geraniaceae
- *Erodium cicutarium* (L.) L'Her

Hydrophyllaceae
- *Phacelia ramosissima* Douglas ex. Lehm.

Iridaceae
- *Iris missouriensis* Nuttall
- *Sisyrinchium idahoense* Bicknell var. *occidentale* (Bicknell) Henderson

Juncaceae
- *Juncus balticus* L.

Lamiaceae
- *Marrubium vulgare* L.

Lemnaceae
- *Lemna minuta* HBK.

Liliaceae
- *Calochortus bruneaunis* Nelson & MacBride
- *Fritillaria atropurpurea* Nuttall

Loasaceae
- *Mentzelia dispersa* Watson

Loranthaceae
- *Arceuthobium camplypodium* Engelmann
- *Phorodendron juniperinum* Engelmann ex Gray var. *juniperunium*

Malvaceae
- *Sidelcea oregana* (Nuttall ex. Torrey & Gray) Gray ssp. *spicata (*Regel) C.L. Hitchcock

Nyctaginaceae
- *Abronia pogonantha* Hiemerl

Onagraceae
- *Epilobium ciliatum* Raf. ssp. *ciliatum*
- *Gayophytum diffusum* Torrey & Gray ssp. *parviflorumm* Lewis & Szweykowski
- *Oenothera caespitosa* Nuttall. ssp. *marginatus*
- *Oenothera xylocarpa* Coville

Papaveraceae
- *Argemone munita* Durand & Hilgard ssp. *rotundata* (Rydb) G. Ownbey

Poaceae
- *Alopecurus aequalis* Sobol
- *Agrostis exarata* Trin. var. *pacifica* Vasey
- *Agrostis filiculmis* M.E. Jones
- *Agrostis stolonifera* L. var. *major* (Gaudin) Farw.
- *Agrostis variabilis* Rydberg
- *Agropyron pectiniforme* Roemer & Schultes
- *Agropyron trachycaulum* (Link) Malte.
- *Bromus tectorum* L.
- *Distichilis spicata* (L.) Greene var. *stolonifera* Beetle
- *Distichilis spicata* (L.) Greene var. *stricta* (Torrey)Beetle
- *Elymus cinereus* Scribner & Merrill var. *cinereus*
- *Hordeum brachyantherum* Nevski
- *Hordeum jubatum* L. ssp. *jubatum*
- *Muhlenbergia asperifolia* (Nees & Meyer) Parodi
- *Muhlenbergia richardsonis* (Trin.) Rydberg
- *Oryzopsis hymenoides* (Roemer & Schultes) Ricker var. *hymenoides*
- *Phleum pratense* L. var. *pratense*
- *Poa compressa* L.
- *Poa incurva* Scribner & Williams
- *Poa nevadensis* Vasey ex Scribner var. *juncifolia* (Scribner) Beetle
- *Poa pratensis* L.
- *Polypogon monspeliensis* (L.) Desf.
- *Puccinellia nuttalliana* (Schultes) A.S. Hitchcock
- *Sitanion hystrix* (Nuttall) J.G. Smith
- *Stipa comata* Trin. & Rupr.
- *Stipa coronata* Thurber var. *depauperata*
- *Stipa speciosa* Trin & Rupr.
- *Vulpia bromoides* (L.) S.F. Gray

Polemoniaceae
- *Eriastrum wilcoxii* (A. Nelson) Mason
- *Gilia* sp. (annual)
- *Leptodactylon pungens* Torrey ssp. *pulchriflorum* (Brand) Mason
- *Linanthas pachyphyllus* R. Patterson
- *Phlox stansburyi* (Torrey) Heller

Polygonaceae
Bistorta bistortoides (Pursh) Small
Eriogonum kennedyi (Porter ex Watson) var. *purpursii* (K. Brandegee) Reveal
Eriogonum umbellatum Torrey var. *dichrocephalum* Gandog.
Eriogonum watsonii Torrey & Gray
Eriogonum wrightii Torrey ex Bentham var. *subscaposum* Watson
Polygonum aviculare L.
Rumex crispus L.
Rumex salicifolius Weinm.

Portulacaceae
Calyptridium monospermum Greene
Lewisia rediviva Pursh ssp. *minor* (Rydberg) N. Holmgren

Pinaceae
Pinus jeffreyi Grev. & Balf.
Pinus monophylla Torrey & Fremont

Ranunculaceae
Ranunculus aquatilis L.
Ranunculus cymbalaria Pursh var. *saximontanus* Fernald

Rhamnaceae
Ceanothus velutinus Douglas ex Hooker var. *velutinus*

Rosaceae
Amelanchier utahensis Koehne. ssp. *utahensis*
Geum macrophyllum Willd.
Holodiscus dumosus (Nuttall) Heller var. *glabrescens* (Greenman) C.L. Hitchcock
Potentilla biennis Greene
Potentilla diversifolia Lehm.
Potentilla rivularis Nuttall var. *millegrana* (Engelmann) Watson
Prunus andersonii Gray
Purshia tridentata (Pursh) DC.
Rosa woodsii Lindley var. *ultramontana* (Watson) Jepson

Rubiaceae
Galium trifidum L. var. *pusillum* Gray

Salicaceae
Salix exigua Nuttall
Salix lasiandra Bentham var. *caudata* (Nuttall) Sudworth
Salix lutea Nuttall

Scrophulariaceae
Castilleja applegatei Fernald
Mimulus coccineus Congdon
Mimulus guttatus Fisch. ex DC. ssp. *guttatus*

Scrophulariaceae (concluded)
Penstemon rydbergii A. Nelson var. *varians* (A. Nelson) Cronquist
Penstemon speciosus Douglas ex Lindley
Verbascum thapsus L.
Veronica peregrina L. ssp. *xalapensis* (HBK) Pennell
Veronica americana (Raf.) Schwein. ex Bentham

Solanaceae
Nicotiana attenuata Torrey ex Watson

Urticaceae
Urtica dioica L. var. *angustifolia* Schelcht
Urtica dioica L. var. *holoserica* (Nuttall) C.L. Hitchcock

Zannichelliaceae
Zannichellia palustris L.

APPENDIX E

DEER STUDIES

CASA DIABLO GEOTHERMAL DEVELOPMENT PROJECT:

DEER STUDY FINAL REPORT, 1987

Thomas E. Kucera
2909 Regent #2
Berkeley CA 94704

INTRODUCTION

Proposals have been made to develop geothermal electric generating plants in the southwest portion of Long Valley in Mono County, California. These developments, including those known as PLES I and MP II and III and referred to collectively as the Casa Diablo Geothermal Project, have raised concerns with respect to potential deleterious impacts on migratory mule deer (*Odocoileus hemionus*) which use the project area and vicinity. The Biotic Assessment of the project prepared in January 1987 was considered by the management agencies involved to be deficient in data on deer in the area. The present investigator was subsequently contracted to gather data to allow an assessment of the importance of the area to deer through an annual cycle, i.e., spring, summer and fall. No wintering activity is to be expected. This report concerns the periods of spring migration, summer, and the fall migration, 1987.

The Eastern Sierra Nevada is known for its visual and biological resources, and the quality of the natural environment. Among the most important components of this natural environment, symbolically, esthetically and economically, are the impressive numbers of mule deer. Only in the last three years has intensive ecological research on these animals been conducted. It is now known that more than half of the 6000 deer which winter near Bishop migrate to the north and pass near the town of Mammoth Lakes to get to their summer ranges (Kucera, unpubl.). The annual life cycle of deer in the Eastern Sierra Nevada may be divided into four periods: winter, spring migration and staging, summer, and fall migration. These seasonal movements are a response to the seasonal availability of habitat, and as parts of a component system, all are important in maintaining deer populations.

Most deer in this part of the Eastern Sierra winter at lower elevations some 20 airline miles to the southeast and east of the proposed geothermal area (Figure 1). Several "herds" as defined by the California Department of Fish and Game (DFG) are of concern in the present situation. These are the Buttermilk and Sherwin Grade herds, which winter in Round Valley, at the base of the eastern escarpment of the Sierra Nevada just west of Bishop, and the Casa Diablo herd, which winters between the Benton Range and the White Mountains, from the Casa Diablo Peak area north past the town of Benton (DFG 1984, 1985a, 1985b).

The spring migration begins in April, when deer leave their winter ranges and move to intermediate altitudes. They congregate in "holding areas" for as long as six weeks, feeding on spring vegetation and regaining condition lost over the winter, until they move to summer ranges. Here, typically at higher elevations and frequently west of the Sierra crest, fawns are produced and reared. The fall migration back to the winter range typically is more rapid than that of the spring, and often is patterned by fall storms. Deer arrive on the winter range during September, October, and November, breed in December and January, and begin the annual cycle again.

The objective of the present work is to describe and quantify the amount, timing and specific locations of mule deer use of the Casa Diablo Geothermal Project Area ("Study Area") during the spring, summer, and fall of 1987. This information is

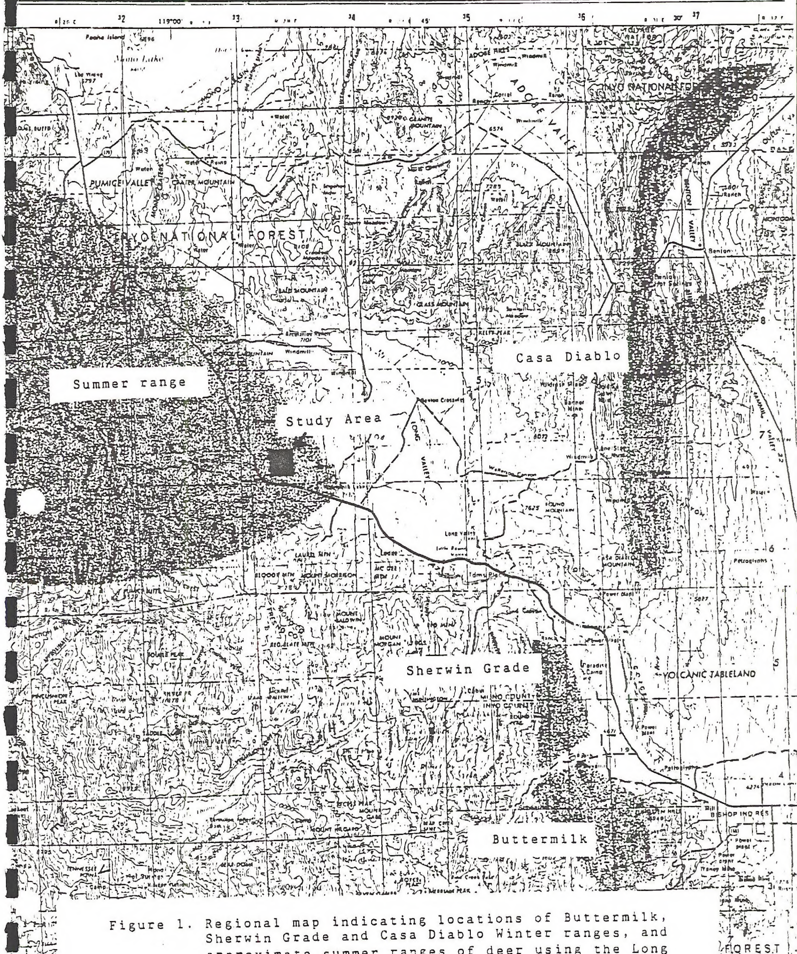

Summer range
Study Area
Casa Diablo
Sherwin Grade
Buttermilk
INYO NATIONAL FOREST
PUMICE VALLEY
ADOBE VALLEY
LONG VALLEY
VOLCANIC TABLELAND
MONO COUNTY
INYO COUNTY
BISHOP IND RES

Figure 1. Regional map indicating locations of Buttermilk, Sherwin Grade and Casa Diablo Winter ranges, and approximate summer ranges of deer using the Long Valley area on migration.

designed to meet the information needs of public resource management and planning agencies with respect to baseline conditions in the Study Area, and to assist in assessing impacts to deer of a geothermal development and designing measures to reduce those impacts.

ACKNOWLEDGMENTS

This investigation was conducted under a contract from Environmental Management Associates, Brea CA. Some of the information presented here is from a larger investigation of Eastern Sierra deer supported by the Bishop Resource Area of the Bureau of Land Management, the California Department of Fish and Game, Inyo and Mono Counties, the University of California, Berkeley, and several private funding organizations. Most of the fieldwork was conducted by Timothy Taylor.

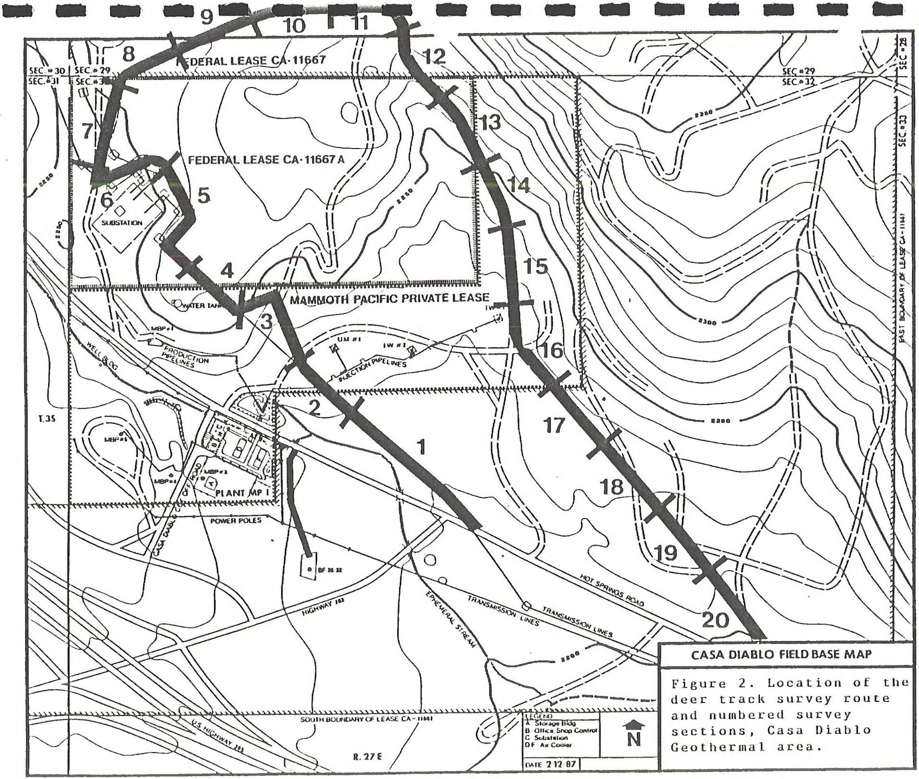
The data in this report are to be used solely for the purposes of planning and analyzing potential environmental impacts of the proposed Casa Diablo Geothermal Project, and are not for publication, citation, or other use without the permission of the author.

STUDY AREA

The Casa Diablo Geothermal Study Area is located in portions of Sections 29 and 32 of T. 3 S, R. 28 E, Mono County, CA (Figures 1 and 2). It is immediately north of Highway 395, approximately 3 miles east of the town of Mammoth Lakes. The land is a mixture of both public and private ownership.

METHODS

A track survey route was laid out on the dirt roads which pass through the Study Area (Figure 2). This route was divided


FEDERAL LEASE CA-11667
FEDERAL LEASE CA-11667 A
MAMMOTH PACIFIC PRIVATE LEASE
SEC. # 30
SEC. # 31
SEC. # 29
SEC. # 32
SEC. # 28
SEC. # 33
EAST BOUNDARY OF LEASE CA-11667
SOUTH BOUNDARY OF LEASE CA-11667
SUBSTATION
WATER TANK
MBP #1
MBP #3
MBP #4
MBP #5
UM #1
IW #1
IW #2
WELL BLDG
PRODUCTION PIPELINES
INJECTION PIPELINES
PLANT MP I
CASA DIABLO CUTOFF ROAD
POWER POLES
DF 36-32
HOT SPRINGS ROAD
TRANSMISSION LINES
TRANSMISSION LINES
EPHEMERAL STREAM
HIGHWAY 203
US HIGHWAY 395
T.3S
R. 27 E
2300
2350
2250
2200
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
LEGEND
A Storage Bldg
B Office, Shop Control
C Substation
DF Air Cooler
N
DATE 2-12-87

CASA DIABLO FIELD BASE MAP

Figure 2. Location of the deer track survey route and numbered survey sections, Casa Diablo Geothermal area.

and marked into 20 sections each 0.1 miles long except Section 1, which was 0.2 miles long. In adition, the dirt road leading from Hot Springs Road to well SF 35-32 was included in the surveys.

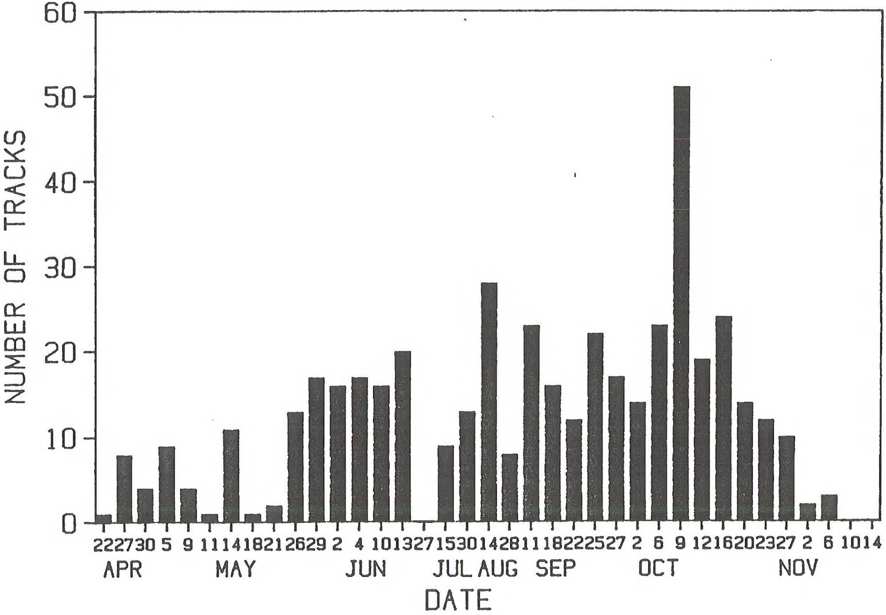
Beginning on 21 April 1987, the entire route was cleared of tracks and a tracking substrate prepared by dragging the route with a "sled" pulled by a vehicle. This was done in late afternoon, and the following morning, the route was walked or driven and all deer tracks observed on the road were counted, both by survey section and by direction of travel. Data recorded were the number of individual deer making the observed tracks and their direction of travel. Because the route was dragged each evening before a survey to obliterate all tracks, the tracks counted on the surveys were made by animals within approximately the previous 12-18 hours. Recording tracks by survey section was designed to give a quantitative picture of the local pattern of deer movement in the Study Area. Recording tracks by direction of movement was designed to allow separation of back-and-forth or very localized movements from migrational movements.

RESULTS

1. Timing of deer activity

Figure 3 shows the total number of tracks made by individual deer throughout the period of study, presented without regard to direction of movement or location. During the spring (22 April-13 June), a pattern of gradual increase in the number of tracks is apparent, with the greatest number of tracks, 20, on 13 June. Subsequently, use was relatively constant except for July and November surveys, and the survey on 9 October. The low counts in July may have reflected restricted activity during fawning. The

FIGURE 3. TOTAL NUMBER OF DEER TRACKS COUNTED ON SURVEYS, 1987



relatively high 9 October total was no doubt due to migrating animals, and the low counts late in the period reflected the fact that most animals had migrated by mid-November. No major fall storm occurred to trigger a large migration, and this is reflected in the pattern of tracks.

Figure 4 shows the breakdown of tracks counted on the spring surveys by direction of movement. Movements to the north and west are generally in the direction of spring migration; those to the south and east are opposite. Thus, subtracting the south and east-moving tracks from the north and west-moving ones, respectively, yields a crude estimate of the net number of deer moving through between the dragging of the route and the counting of the tracks. This is shown in Figure 5, in which the number of tracks heading south was subtracted from those heading north, and the number of tracks heading east was subtracted from those heading west, on each survey. Negative numbers may be interpreted as indicating predominantly localized, nondirectional movements. As indicated in Figure 5, most migrational movements in the Study Area occurred throughout late April and May. Beginning in late May, the negative net track numbers indicate fewer directional or migrational movements and more local movements, likely from deer on what will be their summer range.

Figure 6 shows the breakdown of tracks counted on the summer and fall surveys by direction of movement. Opposite that of the spring pattern, movements to the south and east are generally in the direction of the fall migration; those to the north and west are opposite. Figure 7 presents the number of tracks heading north subtracted from those heading south, and the number of

FIGURE 4. DEER TRACKS BY DIRECTION OF MOVEMENT IN THE PLES GEOTHERMAL SITE, SPRING 1987

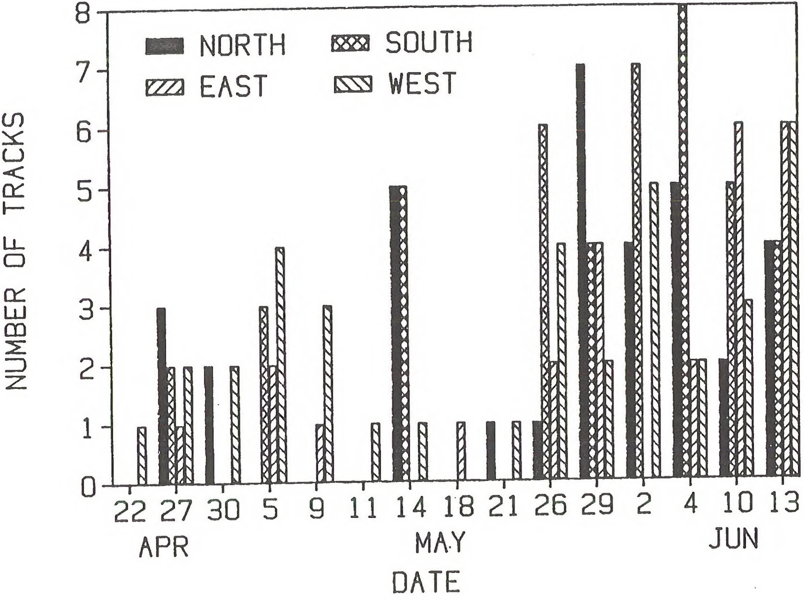


FIGURE 5. NET DEER TRACKS BY DIRECTION OF MOVEMENT IN THE PLES GEOTHERMAL SITE, SPRING 1987

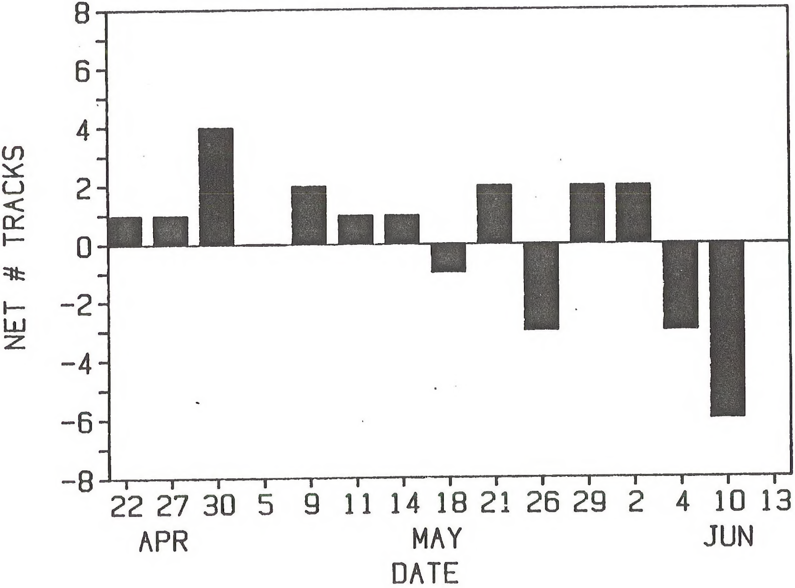


FIGURE 6. DEER TRACKS BY DIRECTION OF MOVEMENT IN THE PLES GEOTHERMAL SITE, SUMMER-FALL 1987

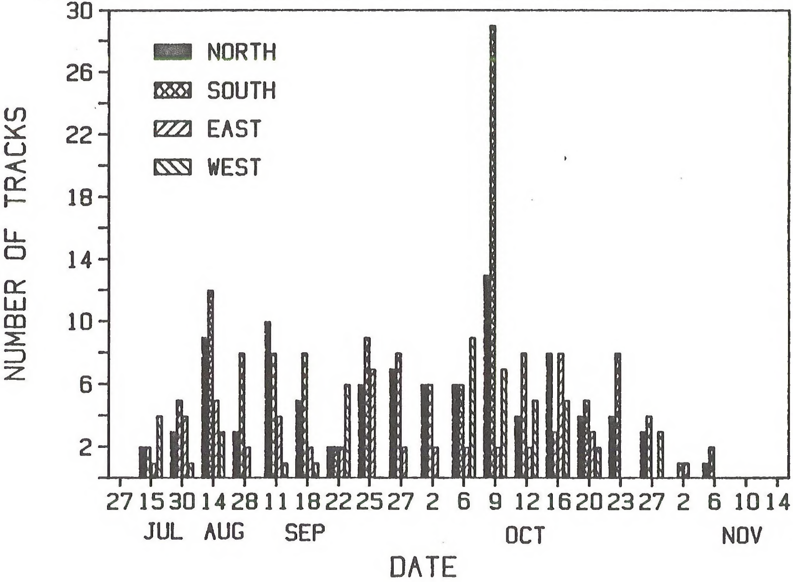
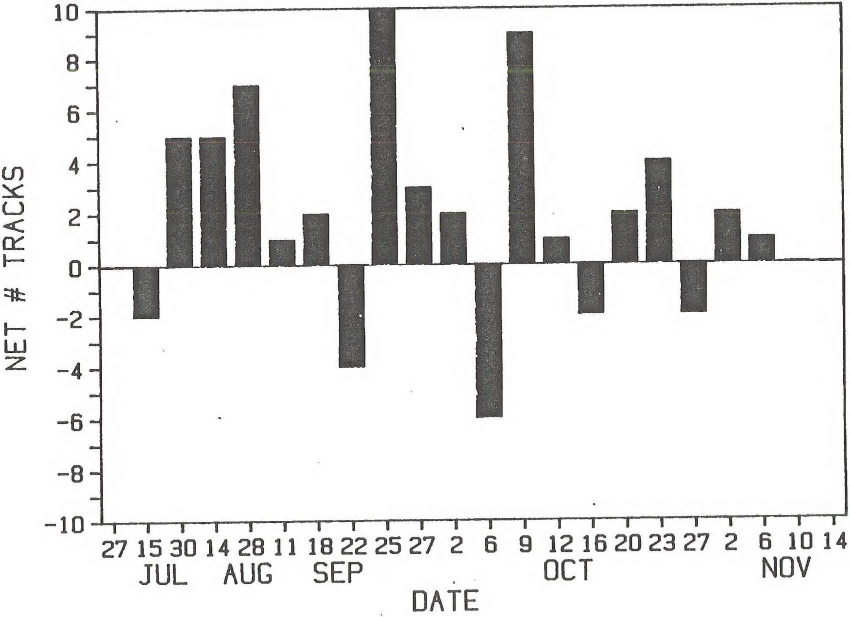


FIGURE 7. NET TRACKS BY DIRECTION OF MOVEMENT IN THE PLES GEOTHERMAL SITE, SUMMER-FALL 1987



tracks heading west subtracted from those heading east, on each survey. The pattern of net tracks in Figure 7, however, yields no straightforward interpretation. The period of summer residency, July through September, shows a predominantly positive net number of tracks, a period during which, if movements were predominantly local, one would expect a balance of approximately zero or below.

2. Locations of deer movements

Figure 8 presents the total number of deer tracks by survey section counted during the spring (22 April-13 June) of 1987. The large number of tracks indicated for Section 1 is somewhat misleading because that section is twice as long as the others. With this in mind, the distribution of tracks in the survey sections appears rather uniform during the spring. In contrast, the distribution of tracks in the survey sections during summer and fall (27 June-14 November) (Figure 9) is more heavily weighted toward the first 10 sections, although deer activity is present in all.

The net tracks by survey section in the spring (Figure 10) show no consistent pattern of movements. It is apparent that directional movements occurred in Sections 8, 10-12, and 18-20, which correspond to the most northerly and northwesterly, and southwesterly portions, respectively, of the Study Area.

The deer activity between June and November can be divided into the periods of summer residency and fall migration. Because there was no major fall storm to elicit one major wave of migration, the fall migration period will somewhat arbitrarily be defined as starting with the 9 October survey. This date is supported by other observations in the vicinity of the study

FIGURE 8. TOTAL NUMBERS OF TRACKS COUNTED BY SURVEY SECTION IN THE PLES GEOTHERMAL SITE, SPRING 1987

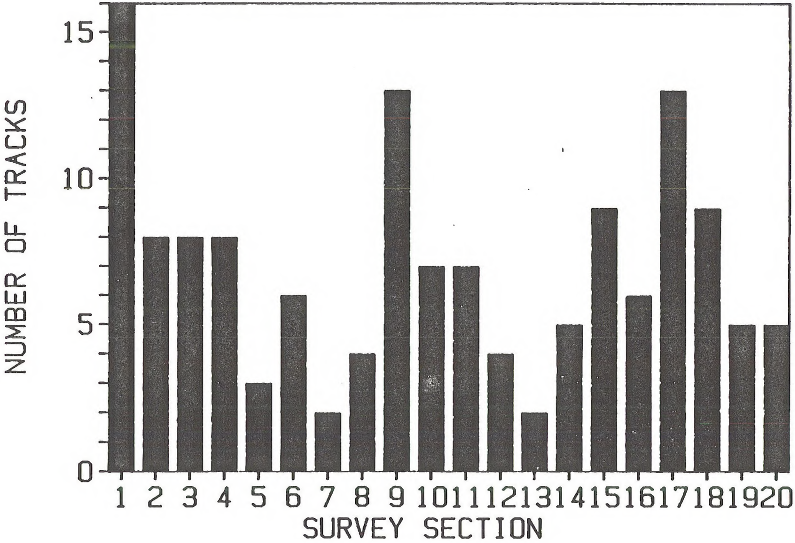


FIGURE 9. TOTAL NUMBERS OF TRACKS COUNTED BY SURVEY SECTION, PLES GEOTHERMAL SITE, SUMMER-FALL 1987

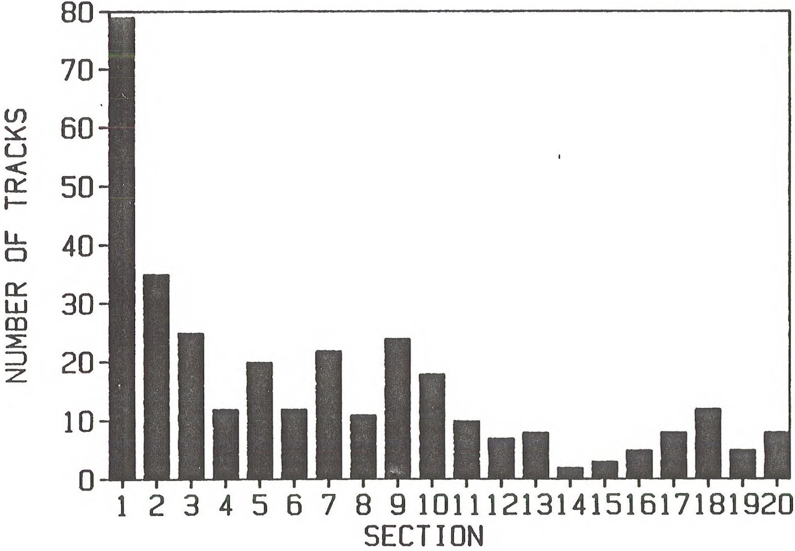
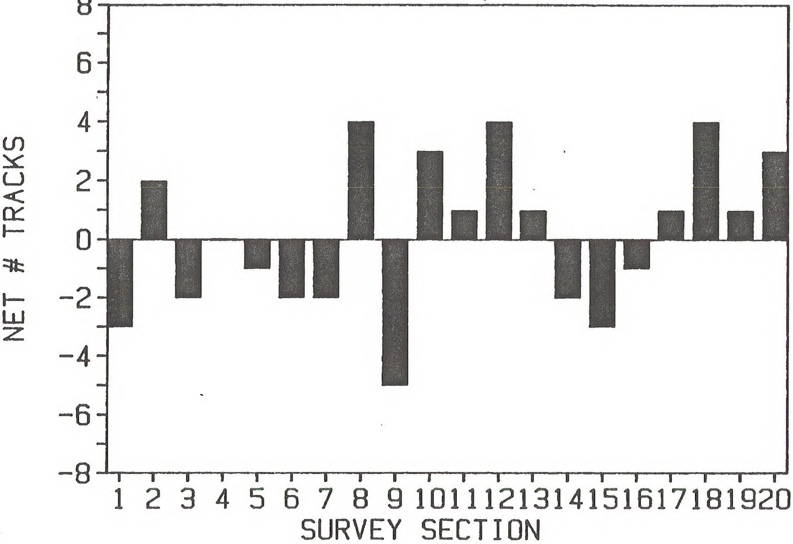


FIGURE 10. NET NUMBERS OF TRACKS BY SURVEY SECTION, PLES GEOTHERMAL SITE, SPRING 1987



area. Figure 11 shows the tracks by survey section divided into summer and fall migration periods. These comprise 12 and 10 surveys, respectively. No consistent patterns are obvious, except that more tracks were counted in Section 1 during migration than during summer. Total tracks were 168 in summer and 158 in fall.

On the road to well SF 35-32, single sets of west-moving tracks were observed on 10, 18, 21, and 26 May. No tracks were observed here on any survey during the summer or fall.

Throughout the survey period, deer were observed visually on only 3 occasions while conducting surveys. On 4 June, 2 adult females were seen near Sections 10 and 11. On 8 October, 5 adult females, 5 fawns and 1 yearling male were seen between Sections 9 and 12. On 26 October, 4 adult females and 1 fawn were seen in Section 10. The summer range of one doe radio-collared in 1984 on the Sherwin Grade included part of the Study Area in 1987, as in previous years.

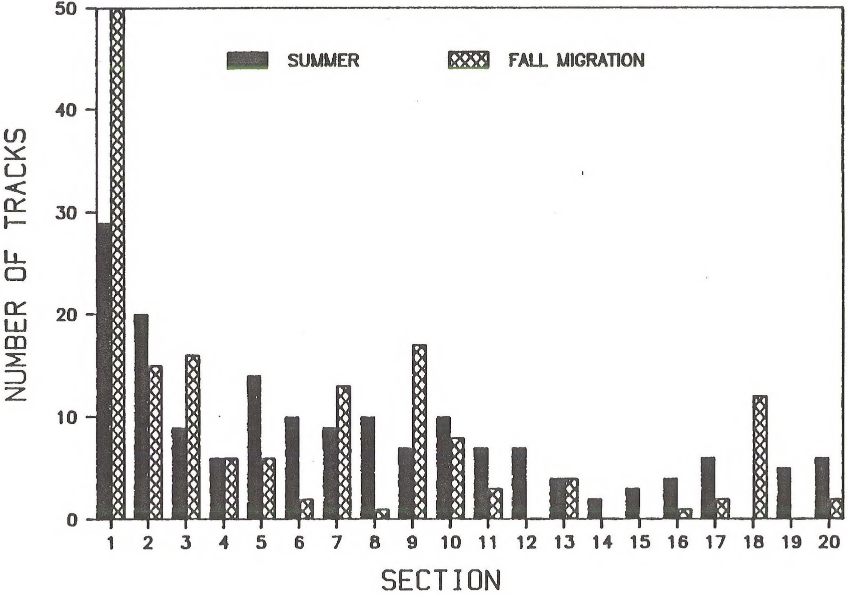
No specific areas of deer movement or well-defined concentration areas were apparent from covering the area on foot during any period.

DISCUSSION

Results of the 1987 track surveys indicate a generally somewhat dispersed pattern of deer activity in and movement through the Study Area. Activity was recorded throughout the spring, summer, and fall periods. No well-defined migration trails were observed, and the track counts indicated deer activity in all sections.

The number of animals involved in the spring migration can be at least roughly estimated. On the assumption that the period

FIGURE 11. TOTAL DEER TRACKS BY SUMMER AND FALL MIGRATION, PLES GEOTHERMAL SITE, 1987



of spring migration was 15 April to 2 June, the 12 surveys covered approximately 25% of the 48 days in this period. The net number of tracks in this period was 13 (Figure 5). Assuming this to be a reasonable approximation of the number of deer actually moving through between the time the area was dragged and when the tracks were counted the next morning, a total of 52 (13/0.25) deer moved through the Study Area during the survey period. This does not take into account those deer that may have moved through during the day. Making the assumption that 75% of deer would migrate at night (between dragging and counting) and 25% would migrate during the day, a grand total of 69 (45/0.75) deer moving through during the spring period can be estimated, given the stated assumptions.

This estimate of 69 deer is meant only as an approximation of the number of deer using the Study Area on spring migration. Potential sources of error, e.g., multiple counts of the same animal, or tracks missed because of poor tracking substrate, are impossible to quantify. However, the precise number is not important; what matters is the estimate of magnitude. There certainly are not hundreds or thousands of animals using this area, as is the case in other local areas, but likely there are dozens. This movement does not seem to be concentrated in any localized portion of the Study Area, but is dispersed throughout it, which may not be unexpected given its relatively small size and lack of extreme topography.

During the summer, the number of tracks counted on the various surveys varied from 0 to 29, indicating a moderate amount of summering activity. There is no way to determine absolute numbers of animals from these track counts, but 6-10 might be a reasonable guess. Fawns were produced in the area; the first fawn tracks were observed on 14 August. Given an average fetal rate of 1.5/doe, the deer summering in the area would produce something like 10-15 fawns.

Attempting to estimate even crudely the number of animals passing through on fall migration, given the unpredictably pulsed pattern of the fall 1987 migration in addition to the problems of estimation discussed above, is not meaningful. One can safely assume the magnitude of the fall migration to be that of the spring plus that year's fawns. Deer movement through the area in the fall was apparent, and, as in the spring, the precise number is not important; again, what matters is the estimate of magnitude. As in the spring, it is likely that there are dozens, dispersed throughout.

Deer from three designated "herds" are involved: the Buttermilk, Sherwin Grade, and the Casa Diablo herds. Radioed or otherwise marked deer from all three herds have been observed in the vicinity of the Study Area (Kucera, unpubl., Taylor 1988).

Recent radio-telemetry information indicates that most of the Buttermilk and Sherwin Grade deer which migrate north do so along the base of the mountains west of Highway 395 (Kucera, unpubl.). Likewise, most Casa Diablo deer move along the base of the Glass Mountains northeast of the Study Area (Taylor 1988). A portion of each herd, however, does move near or right through the Study Area. One deer from the Sherwin Grade range summered within a portion of the Study Area. Taylor (1988) reported that no radioed deer from the Casa Diablo herd migrated near the Study Area, but several ear-tagged deer were seen within several kilometers. Although Figure 3 in Taylor (1988) indicates a major migration route nearby, apparently on the basis of the sightings of the ear-tagged animals, the present study found no evidence of a major route through the Study Area. The present track data, as well as deer sightings, indicate light to moderate and relatively dispersed deer activity.

Impacts of geothermal development on these summering and migrating deer are difficult to predict precisely, but in a general sense are a function both of the location, amount and kinds of changes associated with the development, and of the availability of potential alternate travel routes. It was the case that deer activity was rather dispersed throughout the area. The locations of the proposed power plant sites are shown in Figure 12. These occur most closely to Survey Sections 1 and 15-17 (Figure 2). Additional facilities likely will include a number of wells, pipelines, and a transmission line, as well as the power plants. Section 1 had relatively high deer use, and Sections 15-17 relatively low (Figures 6 and 7). Assuming a "worst case" scenario, one in which deer completely avoid the proposed facilities and associated human disturbance, it is difficult to see how making several dozen deer move several hundred yards around the facilities would constitute a great hardship. Given the existing terrain, such an avoidance would likely have a trivial impact on migrating deer. Of course, certain facilities, e.g., fences, pipelines, etc., could be designed to minimize any impacts to deer and to facilitate their passage. Summer use by deer would be restricted by the developments and human activity, with a consequent lowering of carrying capacity and decreased fawn production.

From the standpoint of deer migration and summer use, the locations of the presently proposed facilities (Figure 12) are less preferable than the initially proposed site (Figure 9 in Kucera 1987). The present proposal has would have the new power plants across Hot Springs Road from the existing plant, thus effectively increasing the area impacted by the project. In general, the more concentrated an area of disturbance, the less will be its deleterious impact. The present configuration, however, apparently is preferable from the standpoint of minimizing visual impacts of the project.

At present, alternate routes for migration exist, giving deer an opportunity to avoid the project area if developed. However, there are proposals for additional developments in the region, e.g., the Mammoth/Chance geothermal project, the Doe Ridge project, the Sherwin Bowl Ski Area, the Snowcreek development, Juniper Ridge, etc. Although it is impossible to discuss thoroughly the impacts of a project without reference to the context in which that project occurs, a regional summary and analysis taking such additional projects into account are not within the scope of the present work. No doubt the consequences of some of these proposed projects, because of their nature, size, and/or geographical location, are potentially much greater than those to be anticipated from Casa Diablo. Others may be more benign. The present study was not designed to evaluate cumulative impacts outside of the Study Area.

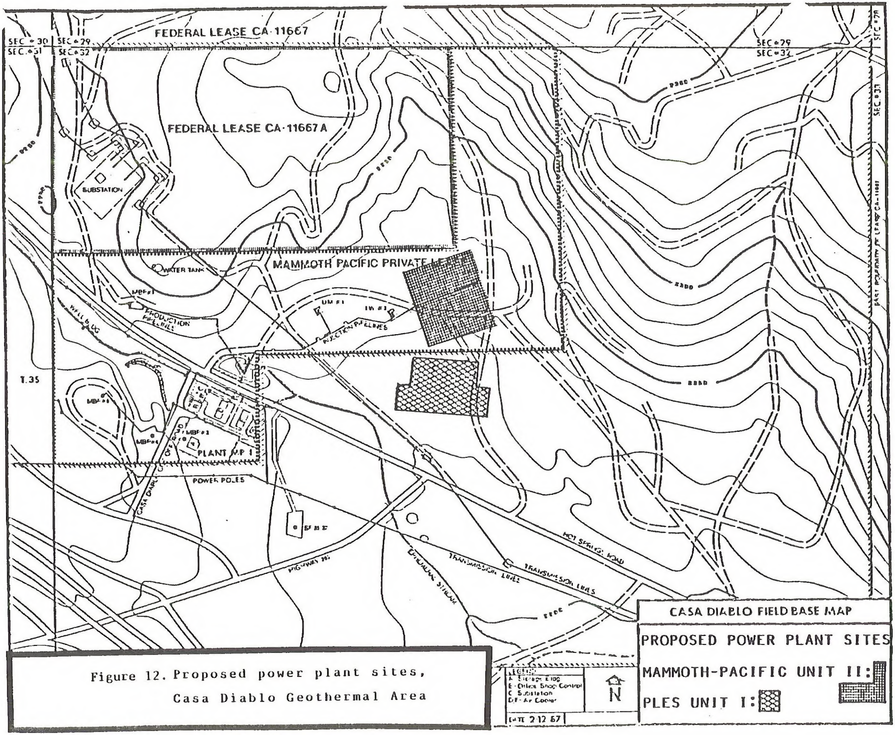

FEDERAL LEASE CA-11667
SEC. 30
SEC. 31
SEC. 29
SEC. 32
SEC. 29
SEC. 32
SEC. 28
SEC. 33
FEDERAL LEASE CA-11667 A
SUBSTATION
WATER TANK
MAMMOTH PACIFIC PRIVATE LEASE
MBF#1
WELL & UG
PRODUCTION PIPELINES
UM #1
IW #1
INJECTION PIPELINES
T.3S
MBF#5
MBF#4
MBF#3
PLANT M.P. I
CASA DIABLO OFF ROAD
POWER POLES
HIGHWAY 395
HOT SPRINGS ROAD
TRANSMISSION LINES
TRANSMISSION LINES
EAST BOUNDARY OF LEASE CA-11667
7200
7300
7400
CASA DIABLO FIELD BASE MAP
PROPOSED POWER PLANT SITES
MAMMOTH-PACIFIC UNIT II: ▦
PLES UNIT I: ▩
LEGEND
A - Storage Bldg
B - Office Shop Control
C - Substation
D,F - Air Cooler
N
DATE 2-12-87

Figure 12. Proposed power plant sites, Casa Diablo Geothermal Area

The present investigation and discussion indicate that the Casa Diablo Geothermal Project Area exhibits a light to moderate amount of deer activity in summer and during the fall migration. Considered by itself, it will likely not have a major impact upon the summer residents or on fall migration. It is likely that the earlier proposed site location, adjacent to the existing power plant, would have less of an impact both to summer resident and migratory deer than the alternatives, across Hot Springs Road. There will be loss of summer habitat causing some reduction in local carrying capacity and fawn production. Regarding migration, in the worst and unlikely case that deer avoid the project entirely, there are at present alternate routes available to allow migrating deer to reach their summer ranges. Thus, the Casa Diablo Geothermal Project by itself will likely have minimal negative impact.

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MIGRATION AND SEASONAL HABITATS OF THE CASA DIABLO DEER HERD

CASA DIABLO DEER STUDY

March 1988

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MIGRATION AND SEASONAL HABITATS OF THE CASA DIABLO DEER HERD

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Bishop, CA. 93514

ABSTRACT: One hundred and seventeen mule deer, _Odocoileus hemionus hemionus_, were captured on wintering areas from January-March 1986 and January-March 1987. Twenty-seven females and 1 adult male were radio-collared and monitored for two spring and two fall migrations in order to delineate migration routes and seasonal ranges. Timing of spring migration was similar during both years despite extremes in severity of winters. Two radio-collared does utilized different spring migration routes and wintering areas in consecutive years. Timing of fall migration was correlated with snowfall in 1987, but not in 1986. Deer remained on holding areas and delayed migration for up to 6 weeks during both spring and fall. Fifteen radio-collared deer occupied summer range on the east slope of the Sierra Nevada; 14 of these utilized aspen riparian habitats. Three radio-collared does crossed the Sierra crest to west side summer ranges. Those radio-collared does occupying summer range in Jeffrey pine (_Pinus jeffreyi_) habitat had larger home ranges than those in more diverse areas. All radio-collared deer exhibited strong fidelity to summer home ranges. Water was found to be the factor most limiting deer distribution and densities throughout portions of winter and summer ranges.

INTRODUCTION

The Rocky Mountain mule deer is the most adaptive and widespread western ungulate (Poole 1976). However, a decline of mule deer in the west has been a major concern of many state conservation agencies (Julander and Low 1976). A general statewide decline in California's deer herds has been occurring since the mid 1950's (Bertram and Rempel 1977, Dasmann 1981). Longhurst et al. (1976) concluded that the decline in California has resulted from a number of different causes including diminishing food supplies and loss of habitat resulting from changes in burning, logging, grazing practices, and other land use factors. On lower western slopes of the Sierra Nevada, increasing urbanization, recreational developments, construction of reservoirs and other land uses have resulted in a serious decline in deer numbers (Dasmann 1981). Recent plans for recreational, urban, geothermal, and hydropower developments in areas of critical mule deer range on the east slope of the Sierra Nevada in Mono County have prompted the California Department of Fish and Game to conduct this study of the Casa Diablo deer herd.

The Casa Diablo herd, which consists of an estimated 1,500 animals, is the smallest of five migratory mule deer herds occurring in Mono County (Thomas 1984). Since this herd generally was known to occupy seasonal ranges throughout the southern and central portion of Mono County (where the majority of development is occurring) it was imperative that studies be conducted in order to delineate all critical habitats used by this herd. To effectively manage migratory deer in the Sierra it is crucial that migration routes and all seasonal habitats be delineated (Bertram and Rempel 1977). Prior to this study, little was known about specific locations of migration routes, holding and summering areas, and transitional ranges of the Casa Diablo herd.

The major objectives of this study, which was conducted from January 1986-January 1988, were to (i) delineate all critical habitats used by the Casa Diablo deer herd; (ii) analyze the quality and quantity of all critical habitats defined; (iii) assess the impacts of land uses, existing and proposed, on critical habitats; (iv) identify habitat factors limiting the herd; and (v) formulate recommendations to reduce the impacts of these factors.

STUDY AREA

The Casa Diablo deer herd occupies approximately 2,200 km in Mono County, California. The herd winter range, located on the Inyo National Forest in southeastern Mono County (Figure 1), encompasses approximately 260 km , varying in elevation from 1,640-2,450 m. Winter range vegetation is a Great Basin sagebrush type, consisting mainly of big sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), and rubber rabbitbrush (*Chrysothamnus nauseosus*). Singleleaf pinyon pine (*Pinus monophylla*) - western juniper (*Juniperus occidentalis*) woodland dominate vegetation between 1,950-2,450 m. Terrain is moderately sloping with soils consisting of an admixture of sandy loams which are generally shallow and rocky (Thomas 1984). Average annual precipitation, measured

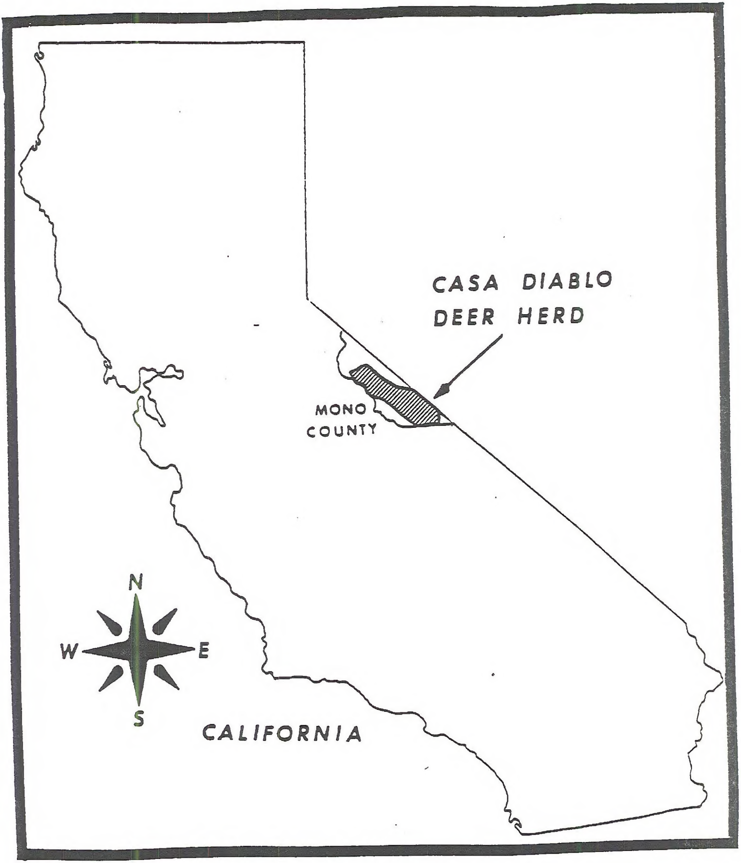
CASA DIABLO
DEER HERD
MONO
COUNTY
N
W
E
S
CALIFORNIA

Figure 1. Location map, Casa Diablo deer herd.

at the Calif. Agric. Inspect. Sta. in Benton, California, is 150 mm, occurring mostly as snow in January and February.

The Casa Diablo winter range was divided into six subwintering areas based on major areas of deer concentration (Figure 2). From north to south these wintering areas include: Truman Meadows, located approximately 13 km north of Benton, California near the California-Nevada state line; Marble Creek, located approximately 7 km south of Benton at the base of the western escarpment of the White Mountain range and east of U.S. Hwy 6; The Blind Spring Hills area, located due west of Marble Creek and immediately west of Hwy 6 in the Benton Mountain Range; Chidago Flat, located approximately 21 km south of Benton and 14 km west of Hwy 6; Casa Diablo Mountain, located 29 km south of Benton and 14 km west of Hwy 6; and The Volcanic Tablelands, located 43 km south of Benton and 7 km north of Bishop, California.

Deer from the Casa Diablo herd occupy approximately 1,940 km of summer range on the Inyo National Forest in west-central Mono County, mainly along the east slope of the Sierra Nevada (Figure 2). Portions of Madera County and Tuolumne counties on the west side of the Sierra are also used to a limited extent by summering deer. Nine major summer range habitat types, varying in elevation between 2,130-2,950 m were described in areas used by radio-collared and ear tagged deer (USDA 1981).

Singleleaf Pinyon Pine-Western Juniper----This type occurs mainly on dry south and east facing slopes of the Sierra Nevada and Glass Mountain ranges. Single-leaf pinyon pine is the dominant conifer species between approximately 2,070-2,600 m near Lee Vining and also dominates deer summer range on the west slope of the White Mountains. Associated understory species include curlleaf mountain mahogany (*Cercocarpus ledifolius*), big sagebrush, bitterbrush, and rabbitbrush.

Jeffrey Pine.----This type is open Jeffrey pine (*Pinus jeffreyi*) forest which occurs in large stands between elevations of approximately 2,200-2,450 m. Associated understory species include big sagebrush, bitterbrush, gooseberry (*Ribes* spp.), and mountain snowberry, (*Symphoricarpos vaccinioides*). This is also the dominant vegetation type found on all holding areas used by the Casa Diablo deer herd.

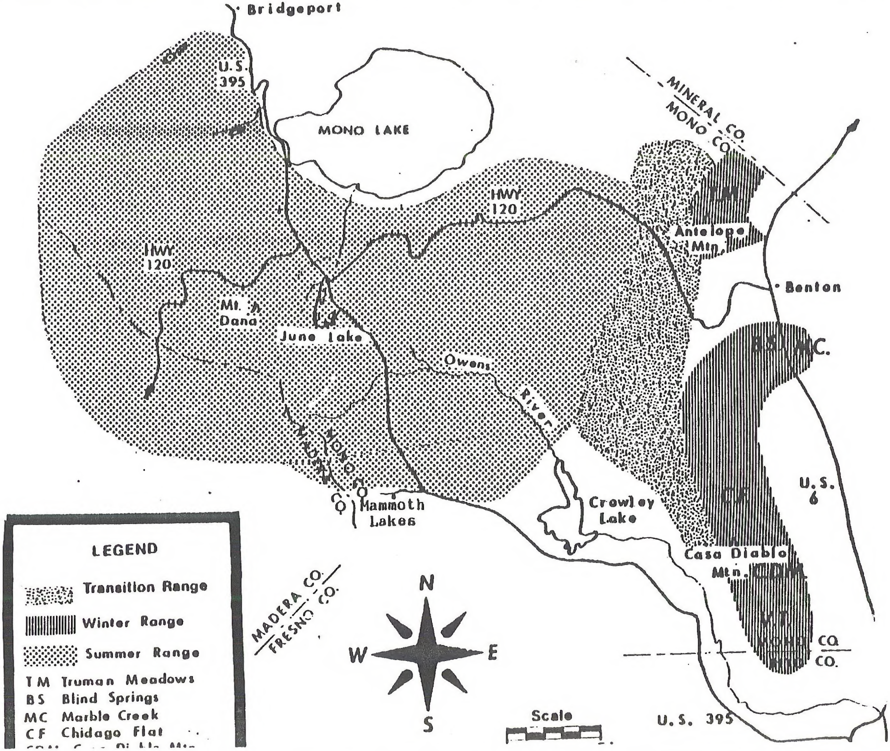
Bridgeport
U.S. 395
MONO LAKE
MINERAL CO.
MONO CO.
HWY 120
HWY 120
TM
Antelope Mtn.
Benton
Mt. Dana
June Lake
BS MC.
Owens River
MADERA CO.
MONO CO.
Mammoth Lakes
Crowley Lake
CF
U.S. 6
Casa Diablo Mtn.
CDM
MONO CO.
INYO CO.
MADERA CO.
FRESNO CO.
N
S
E
W
Scale
U.S. 395
LEGEND
Transition Range
Winter Range
Summer Range
TM Truman Meadows
BS Blind Springs
MC Marble Creek
CF Chidago Flat

Figure 2. Location of Casa Diablo deer herd winter and summer ranges, Mono County, California.

Mixed Conifer Forest.----The codominants of this vegetation type occurring on the east slope of the Sierra Nevada between approximately 2,400 -2,600 m include Jeffrey Pine, white fir (Abies concolor), lodgepole pine (Pinus contorta), and western white pine (Pinus monticola). At higher elevations of the Mixed Conifer type, red fir (Abies magnifica) is an occasional associated species and white fir often occurs in pure stands at lower elevations.

Quaking Aspen Riparian.----This dense cover type occurs within a few meters of most stream channels on the east slope of the Sierra Nevada and throughout the Glass Mountains and is dominated by quaking aspen (Populus tremuloides), willow (Salix spp.), wild rose (Rosa woodsii), gooseberry, and snowberry. Groves of quaking aspen, which provide critical fawning and fawn rearing habitat, also are indicators of moist conditions and are located mainly near high elevation meadows.

Lodgepole Pine Forest.----This forest type is found above the Mixed Conifer type on the east slope of the Sierra and north slope of the Glass Mountains at elevations between approximately 2,600-3,000 m. It is composed of lodgepole pine which often occurs in large, dense, homogeneous stands. Within the lodgepole pine forest perennial grasses and forbs (needle-and-thread grass (Stipa comata), bluegrass (Poa pratensis), bromegrass (Bromus tectorum), lupine (Lupinus duranni), and pussy paws (Calyptridium caudiciferum)), dominate openings of poorly developed, dryer soils.

Montane Meadow.----This meadow type is found mainly at mid and upper elevations on the east slope of the Sierra and throughout the Glass Mountains and is composed primarily of sedges (Carex spp.), and rushes (Juncus spp.), and designates year long water availability. Perennial grasses, forbs, willows, quaking aspen, and lodgepole pine are associated with these meadows.

Whitebark Pine.----This forest type, dominated by whitebark pine (Pinus albicaulis), occurs on high windswept ridges at treeline on the east slope of the Sierra.

Great Basin Sagebrush.----This type generally occurs on dry slopes and plains from 1,220-3,320 m, east of the Sierra Crest. Big sagebrush is dominant with bitterbrush often occurring as a codominant. This type often is found in association with Jeffrey pine.

Montane Chaparral.---This type occurs on open flats and rocky ridges from 2,135-3,050 m. Greenleaf manzanita (Arctostaphylos patula), mountain whitethorn (Ceanothus cordulatus), Chinquapin (Castanopsis sempervirens), and tobacco brush (Ceanothus velutinus), occur as codominants. This type often is found in association with Great Basin sagebrush.

METHODS

Deer were captured on the Casa Diablo winter range from January-February 1986 and January-February 1987 using Clover traps (Clover 1956), baited with alfalfa hay. Three to five trap sites were located throughout each area and prebaited for two weeks with alfalfa hay. Traps were operated on 2-3 days each week until late February, at which time bait acceptance became poor due to the presence of herbaceous growth.

On 26 and 27 February and 7 March 1986, deer were captured and marked on all six subwintering areas (Figure 2) using linear, nylon tangle nets (2 x 90 m) and a Bell Jet Ranger III helicopter (Beasom et al. 1980). Deer were hazed slowly by the helicopter into nets placed at strategic locations, usually preselected by the pilot through aerial reconnaissance. Net sites usually employed natural escape routes, such as ravines. Anywhere from 1-10 deer were captured on several successive drives until desired numbers were obtained for each wintering area.

All deer were physically restrained and marked with two large, plastic, consecutively numbered cattle ear tags (7.5 x 11.5 cm; Apollo Tag Systems), color coded to wintering area. Twenty-six adult females were fitted with radio collars. In addition, one adult male was instrumented with a radio transmitter mounted on an expandable collar to allow for neck swell during the rut. A single adult female was captured on its spring range by use of a tranquilizer dart carrying 3 cc of a Rompon-ketamine hydrochloride mixture, fitted with a radio-collar (.220) and released.

Adult radio collars (159.021-159.450 MHz; Telonics, Inc., Mesa, Arizona), weighed 260-270 g and had an operational life of 24-36 months at 35-75 pulses/minute. Thirteen radios were equipped with mortality sensors that doubled the pulse rate of the signal when an animal was stationary for 3-5 hours.

The locations of all radioed animals were obtained by triangulation from the ground or from a fixed-wing aircraft during the course of the study. Deer were located from the ground at least 2-3 times weekly during the winter and summer months and 5-6 times weekly during spring and fall migrations. Initial ground locations were made from a vehicle equipped with a Telonics TR-2 receiver with an attached programmer/scanner (TS-1) and a base loaded whip antenna. Triangulation bearings were obtained using a hand-held, 2-element antenna (RA-2A; Telonics, Inc., Mesa, Arizona). Visual sightings of radio collared deer were made whenever possible. Radio locations and visual sightings were marked on U.S. Geological Survey 7.5 minute series topographic maps.

Fixed-wing flights were conducted once weekly, weather permitting, during spring and fall migration and once every 2-3 weeks during the winter and summer, usually between 0900 and 1100 hours. Flights were conducted in a Cessna 185 at air speeds of 120-180 km/hour.

Migration routes, holding areas, and winter and summer home ranges were identified and then delineated using radio telemetry. Winter and summer home ranges (Burt 1943), were determined using the Modified Minimum Area Method (Harvey and Barbour 1965). Each home range included a minimum of five relocation points determined from visual observations. Radio-collared deer were considered to show fidelity to a specific seasonal home range if ranges in consecutive years overlapped.

Holding areas were recognized as sites along migration corridors where deer remained for several days or more during migration (Bertram and Rempel 1977). All holding areas identified were designated a number as to the position in which they occur along the migration corridor, e.g., HA-I.

Post season deer composition counts were conducted over the entire winter range by use of a Bell Jet Ranger III helicopter during early January 1986, 1987, and 1988. Spring composition counts were conducted on foot in March and early April of 1986 and 1987 in more accessible portions of the winter range.

RESULTS

CAPTURE AND MARKING

A total of 117 deer (86 females and 31 males) were captured, marked, and released on all of the 6 subwintering areas of the Casa Diablo deer herd (Table 1). Thirty-eight of these were fawns (24 males and 14 females), 72 adult females, and 7 adult males.

TABLE 1. Total Number and Composition of Deer Captured, Marked, and Released on each of the Casa Diablo Wintering Areas. January-March 1986, January-February 1987.

LOCATION	ADULTS		FAWNS		TOTAL
	M	F	M	F	
MC	4	30	11	8	53
BS	2	16	5	1	24
TM	0	6	3	2	11
TL	0	9	3	0	12
CD	0	3	0	0	3
CF	1	8	2	3	14
TOTAL	7	72	24	14	117

MIGRATION CORRIDORS AND HOLDING AREAS

During the two spring and fall periods studied, 22 of 27 radio-collared deer marked on the Casa Diablo winter range in 1986 and 1987 migrated to the west of their respective wintering areas. Five deer, all from the Marble Creek wintering area, migrated to the east, up the west slope of the White Mountains.

Beginning in early April, deer leave their respective wintering areas and move in a westerly direction along separate migration routes toward the Glass Mountains (Figure 3, Appendix Figure 1a). These routes merge at the east end of the Glass Mountains and continue westward along the south slope. The Glass Mountains extend in a westerly direction from Benton, California, and are bordered by Crowley Lake and the Owens River to the south and Hwy 120 to the north. They encompass approximately 256 km with an elevational range of 2,134-3,216 m.

During the spring of 1986, 19 of the 22 radio-collared deer which summered west of the Casa Diablo winter range migrated along the base of the south slope of the Glass Mountains. Deer movements were concentrated between 2,135-2,285 m, along the interface of pinyon-juniper woodland and Great Basin sagebrush habitat types. Deer typically preferred to remain in the more open sagebrush-scrub vegetation while migrating, perhaps in order to avoid predators and to take advantage of herbaceous vegetation occurring there.

Eighteen of the 19 radio-collared deer which migrated along the south slope of the Glass Mountains in spring of 1986, utilized a large spring holding area at the west end of this range near the headwaters of the Owens River. In addition, 16 non-radioed, ear tagged deer were observed on this holding area during the spring and fall migrations of 1986 and 1987 (Appendix Figure 2). This holding area, designated (HA-I), is located 29 km north of the Casa Diablo winter range. The average vertical rise in elevation between HA-I and Casa Diablo deer herd wintering areas is approximately 300 m. HA-I encompasses 26 km , varying in elevation between 2,134-2,256 m. The major habitat type occurring there is a mixture of Jeffrey pine and Great Basin sagebrush vegetation. This area also contained one large wet meadow, known as Alpers meadow, where deer often concentrated in significant numbers during the evening and early morning hours.

Radio-collared deer spent an of average 11 days on HA-I in 1986 (range 1-45), and 4 days (range 1-34) in 1987. Radio-collared deer which migrated to the west of HA-I spent an average of 22 days longer there in 1986, and 15 days longer in 1987, than deer which migrated to the north.

During the spring migration of 1986, 13 of the 18 radio-collared deer which utilized HA-I summered to the north, and 4 to the west. One radio-collared doe was killed by a mountain lion (Felis concolor), on 26 April near Alpers meadow. Its radio-collar was put on another adult doe in the same area on 10 May. This deer never migrated further, eventually summering near Big Springs at the headwaters of the Owens River.

The main migration corridor used by deer summering to the north of HA-I, extends in a northwesterly direction, contouring around the southern end of the Mono Craters toward the Aeolian Buttes (Figure 3, Appendix Figure 1a). Deer were found to cross a two lane section of Hwy 395 near the Aeolian Buttes, before continuing west around the northern end of Grant Lake to another spring holding area (HA-II), located at the foot of the Parker Creek and Walker Creek drainages. HA-II encompasses approximately 5.2 km at elevations ranging from 2,195-2,439 m. The major habitat type occurring on HA-II is a mixture Jeffrey pine and Great Basin sagebrush which include dense pockets of 1-2 m high curlleaf mountain mahogany. HA-II also includes several wet meadows the largest of which is approximately 1 km . During the spring migration of 1986, 12 radio-collared deer, all of which spent some time on HA-I, utilized HA-II

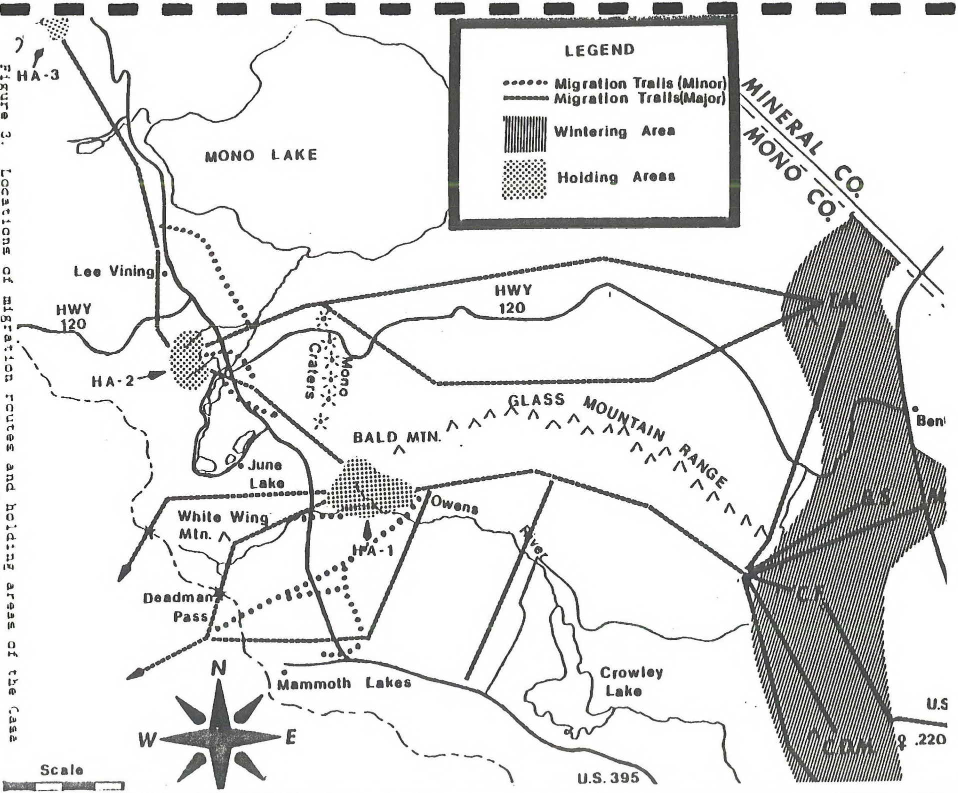
LEGEND
Migration Trails (Minor)
Migration Trails(Major)
Wintering Area
Holding Areas
MINERAL CO.
MONO CO.
MONO LAKE
HA-3
Lee Vining
HWY 120
HWY 120
HA-2
Mono Craters
GLASS MOUNTAIN RANGE
BALD MTN.
June Lake
White Wing Mtn.
HA-1
Owens River
Deadman Pass
Mammoth Lakes
Crowley Lake
U.S. 395
U.S
.220
TM
BS
CF
CBM
Ben
N
W
E
Scale

Figure 3. Locations of migration routes and holding areas of the Casa Diablo deer herd in Mono County, California.

from 1-47 days during April, May, and June. In addition, a total of 5 non-radioed, ear tagged deer were observed on HA-II during the spring migration of 1986 (Appendix Figure 2). Deer traveling to lower elevations did not use HA-II to the extent of those traveling to higher elevations.

One radio-collared doe was found to utilize HA-II during two different periods in the spring of 1986 before moving onto her summer range. This particular doe first arrived on HA-II on 12 April and remained there until 24 April after which time she traveled extensively to the north and west over an area encompassing 20 km at elevations between 2,320-2,750 m. She returned to HA-II for a second time on 2 May and remained there until 5 May, after which time she traveled to the south and east over much of the Reverse Peak area before finally settling down on her summer range on 10 May. Her movements appear to have been directly influenced by weather and its effects on plant phenology on her summer range, which was located within a steep canyon where limited sunlight and cool daytime ambient temperatures resulted in late development of forage.

In 1986, 6 radio-collared deer migrated north of HA-II, 4 of which summered in Lee Vining Canyon, 1 in Lundy Canyon, and 1 near lower Twin Lake. The radio-collared doe which summered near Lower Twin Lake was found to occupy another spring holding area (HA-III), located at the north end of Lower Twin Lake on Honeymoon Flat. She remained on HA-III for 5 days (12-17 June) in 1986, before moving 3 km east to her summer home range. HA-III encompasses 5 km at elevations ranging from 2,120-2,200 m and, like other holding areas, is composed of a mixture of Jeffrey pine and Great Basin sagebrush vegetation (Appendix Figure 1b).

As mentioned previously, 4 radio-collared deer migrated to the west of HA-I (Figure 3, Appendix Figure 1). These deer departed HA-I between 24 and 28 May in 1986 and traveled in a southwesterly direction, crossing what was then a two lane section of Hwy 395 just north of the Crestview maintenance station. One radio-collared doe migrated up the Glass Creek drainage on the north side of White-Wing Mountain before crossing San Joaquin Ridge to the west side of the Sierra. The other 3 radio-collared does migrated around the south side of White-Wing Mountain, two of which crossed San Joaquin Ridge over Deadman Pass (elevation 3,163 m). The other stopped approximately 1 mile east of the ridge where it summered on the south slope of White-Wing Mountain.

Although the winter range of radio-collared female .220, marked on HA-I, was never located, a portion of her migration route was delineated. Her migration route heads in an easterly direction from her summer range, located near HA-I, first contouring along the south slope of the Glass Mountains. It then proceeds through the Chidago Flat area and across the Volcanic Tablelands, after which it crosses Hwy 6, just south of the town of Chalfant and continues into the Piute Creek area of the White Mountains. The remainder of the migration route, like her winter range, was never delineated.

Sixteen of 22 radio-collared deer which summered to the west of the Casa Diablo winter range were monitored for both the 1986 and 1987 spring periods, and all but 2 used the same migration routes. These 2 deer, both from the Truman Meadows wintering area, migrated along the south slope of the Glass Mountains in 1986 in order to reach their summer range destinations. However, in 1987, both of these deer migrated along the north side of the Glass Mountains (Figure 3, Appendix Figure 1a). Doe .450 totally bypassed HA-I which she used in 1986, and migrated directly to her summer range. Doe .315 migrated along the north side of the Glass Mountains to as far as Sagehen Meadow, before turning south to HA-I.

SPRING MIGRATION

A total of 11 radio telemetry flights were made during the spring periods of 1986 and 1987 to locate deer during migration. All monitored deer from the Casa Diablo deer herd were migratory with distinct winter and summer ranges. Despite extreme differences in the amount of snowfall recorded during the winters of 1985-86 and 1986-87, little variation occurred in the overall timing of migration (Figure 4). The winter of 1985-86 was one of the wettest on record in the eastern Sierra, with 745.2 cm of snowfall recorded at 2,378 m at Mammoth Lakes, Mono County (USFS, Unpubl.). In contrast, during the winter of 1986-87, 255.8 cm of snowfall was recorded at the same location.

Deer migrated approximately two weeks later in 1986 than in 1987. However, the overall timing of migration to the summer range between the two years was quite similar. In 1986, deer began leaving the winter range on 3 April, with 50% of all radio-collared deer having migrated by 20 April (Figure 4). By 15 May, all radio-collared deer had left the winter

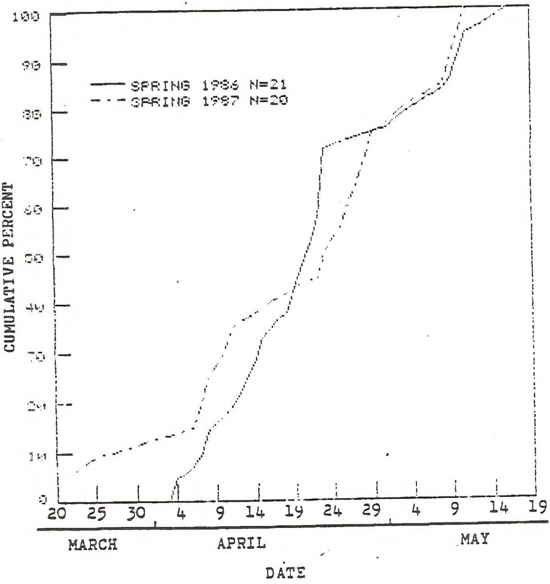

Figure 4. Cumulative percent of radio-collared deer migrating from the Casa Diablo winter range by date.

range.

In spring of 1987, 2 radio-colllared does migrated on 20 and 26 March. However, due to late development of spring green-up on the winter range, no other radio-collared deer were found to migrate until 6 April. By 22 April, 50% of all radio-collared deer had migrated and by 10 May, all had left the winter range. Migration from the winter range in spring of 1987 was more gradual than in 1986, with no peak periods of departure (Figure 4).

Deer that summered at higher elevations did not leave the winter range at a later date than those summering at lower elevations. However, deer which summered at higher elevations, or those having to cross the Sierra crest to gain access to west side summer ranges, did remain longer on spring holding areas. Changes in elevation between winter and summer ranges varied from 2,134-3,354 m. Distances traveled between winter and summer ranges varied from approximately 3.5 to 116 km.

Arrival dates of radio-collared deer on the summer range varied dramatically among some individuals during the two years studied and had no discernible pattern. Five deer arrived from 10-13 days later on their summer ranges in 1987 than in 1986. In contrast, five others arrived from 10-20 days earlier on their summer ranges in 1987 than in 1986.

FALL MIGRATION

Radio-collared deer were monitored for two consecutive fall seasons. Little variation exists in the timing of migration to the winter range between 1986 and 1987. However, migration to the winter range appeared to be less strongly correlated with weather in 1986 than in 1987. This mostly is due to the occurrence of only one minor storm in the fall of 1986, on 24 September. During the 1986 fall migration, 83% of radio-collared deer migrated between 3 October and 8 November (Figure 5). Two radio-collared does remained on their summer ranges until 3 January 1987, when the first significant winter storm occurred.

In 1987, the first radio-collared deer migrated from the summer range on 6 October. Eighty-two percent of radio-collared deer migrated in response to storms which occurred on 11-12, 22-23, and 27-28 October and 2-3 November.

Radio-collared does summering at higher elevations or west of the

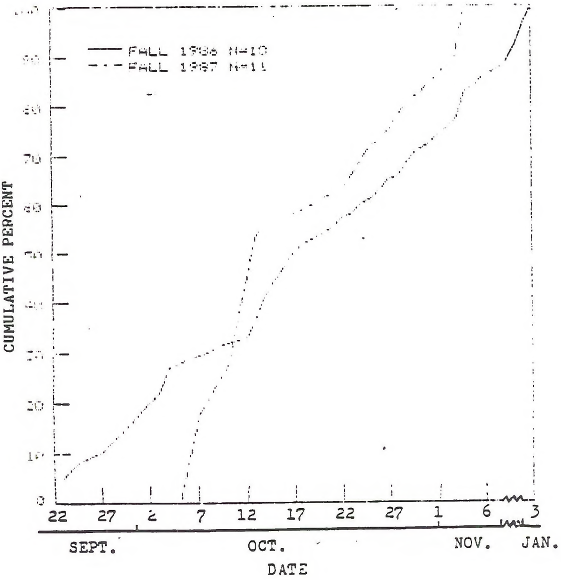

Figure 5. Cumulative percent of radio-collared deer migrating from summer range by date.

Sierra crest did not appear to migrate earlier than those summering at lower elevations. In both years, all deer known to migrate along the south slope of the Glass Mountains spent between 1 and 41 days on HA-I, remaining there until as late as mid-November before migrating further east. Here, a south-facing slope provided snow free areas of abundant browse. Once the deer left HA-I, movement generally was gradual, with deer taking as long as 15 days to reach wintering areas.

WINTER RANGE

Home range sizes for radio-collared deer on the winter range averaged 85 ha (range = 31-154 ha). During the dry winter of 1986-87, 19 of 22 radio-collared deer occupied higher elevation transition range west of their respective wintering areas. All utilized large stands of pinyon pine between 2,135-2,470 m, where they fed extensively on a large crop of pinyon nuts. Light to moderate snow conditions made pinyon nuts readily available throughout the entire winter. Home range sizes on transition range averaged 295 ha (range = 172-384 ha). Deer remained on transition range until approximately mid-March, after which time 16 radio-collared deer moved east an average of 11 km to lower portions of the winter range presumably in search of herbaceous spring forage.

During the winter of 1986-87, three radioed does, all of which were captured on Casa Diablo Mountain in January 1986, never returned to this wintering area (Figure 2). Two of these does spent the entire winter approximately 8 km northwest of Casa Diablo Mountain on transition range near the south end of Banner Ridge. These two does were the first radio-collared deer to migrate in spring 1987, on 20 and 26 March, departing directly from Banner Ridge. The other doe, which migrated along the north side of the Glass Mountains during the 1986 fall migration, traveled only as far as the Sagehen Meadow area where she spent the entire winter. In the spring of 1987, this doe migrated to her summer range directly from the Sagehen Meadow area on 7 April.

In fall of 1987, deer were monitored until 15 December. At this time, only 2 of 11 radio-collared deer had returned to the wintering areas where they were captured. The other 9 occupied transition range west of wintering areas, as they did during the winter of 1986-87.

SUMMER RANGE

Deer from the Casa Diablo herd occupied approximately 2,000 km of summer range throughout west central Mono County, primarily along the east slope of the Sierra Nevada (Figure 2). Fifteen of 22 radio-collared deer which migrated to the west of the Casa Diablo winter range summered on the east slope of the Sierra Nevada, from the Deadman Creek drainage north to lower Twin Lake (Figure 6, Appendix Figure 3). Twelve of these 15 deer summered within a 22 km area, from Grant Lake north to Lee Vining Canyon. A total of 22 non-radioed, ear tagged deer were observed along the east slope of the Sierra Nevada during the summers of 1986 and 1987 (1 June-1 October) (Appendix Figure 2). Radio-collared deer which summered on the east slope of the Sierra occupied home ranges located at an average elevation of 2,547 m (range = 2,135-2,960 m).

Four radio-collared deer summered east of Hwy 395 from the Mono Craters south to O'Harrel Canyon in the Glass Mountains at an average elevation of 2,515 m (range = 2,195-3,050 m). In addition, 10 non-radioed, ear tagged deer were observed east of Hwy 395 between 1 June and 1 October 1986 and 1 June and 1 October 1987 (Appendix Figure 2). Three radio-collared deer summered to the west of the Sierra crest, one in Madera County at Beasore Meadow near Chilkoot Lake, one in Yosemite National Park near Tuolumne Meadows, and one in the upper San Joaquin drainage near Shadow Lake (Appendix Figure 4). Four radio-collared deer, all from Marble Creek, summered on the west slope of the White Mountains directly above the winter range.

Marked deer from the same wintering area occupied portions of summer range in "family groups". This was most evident in deer from Chidago Flat in which 12 of 14 marked animals were found on the same summering area in Lee Vining Canyon. Conversely, marked deer from the same wintering area were also found to disperse to opposite ends of the summer range (Figure 6). For example, one doe from the Blind Spring Hills summered at the southern end of the herd range near the Deadman Creek drainage while another summered at the northern end of the range near lower Twin Lake. Gruell and Papez (1963), also found this to be true of deer in northeastern Nevada, where all deer wintering together did not summer together.

Marked deer from several different wintering areas were found to

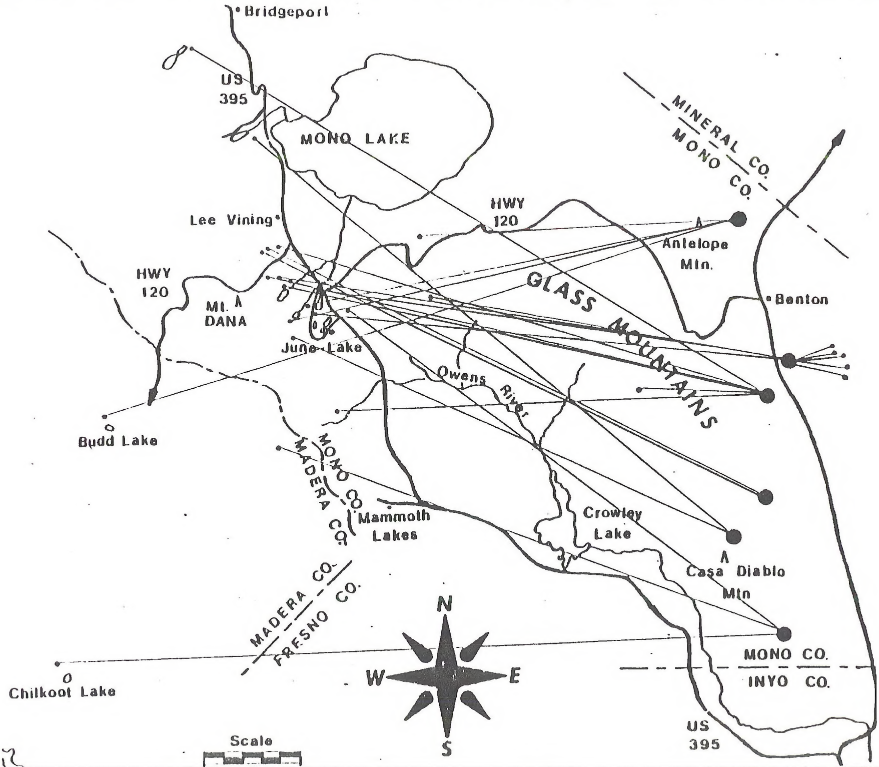
Bridgeport
US
395
MONO LAKE
MINERAL CO.
MONO CO.
HWY
120
Lee Vining
Antelope
Mtn.
GLASS MOUNTAINS
Benton
HWY
120
Mt.
DANA
June Lake
Owens River
Budd Lake
MONO CO.
MADERA CO.
Mammoth
Lakes
Crowley
Lake
Casa Diablo
Mtn
MADERA CO.
FRESNO CO.
N
W
E
S
MONO CO.
INYO CO.
Chilkoot Lake
US
395
Scale

Figure 6. Movements of radio-collared deer marked on wintering areas (large circles) and subsequently found on summer ranges (small circles).

occupy summer range of close proximity and even to have overlapping home ranges. Three radio-collared does, two from Chidago Flat and one from Blind Springs, had overlapping home ranges of 34-111 ha in Lee Vining Canyon on the east slope of the Sierra. Two does, one from Marble Creek and one from Blind Springs, had overlapping home ranges in Bohler Canyon, also located on the east slope of the Sierra.

Many fawning areas or "population centers" were identified on the east slope of the Sierra (Figure 7, Appendix Figure 5). Population centers are described as an aggregation of propagation units where single pregnant does find adequate food, water, and cover to rear fawns (Bertram 1984).

All 16 radio-collared deer monitored for two successive years exhibited strong site fidelity to summer range areas by returning to the same summer range locations in 1987 as in 1986.

SUMMER HABITAT UTILIZATION

Home ranges for deer summering on the east slope of the Sierra Nevada averaged 100 ha (range = 34-167 ha). Quaking aspen riparian habitat was the major type most utilized by radio-collared deer from the Casa Diablo herd. Fourteen of the 15 monitored does which summered on the east slope of the Sierra Nevada mountains were found to have summer ranges typically consisting of a mosaic of different habitat types centered around some portion of a riparian area. Seven of these does utilized quaking aspen riparian vegetation occurring along stream channels winding through open areas of Great Basin sagebrush and montane chaparral. These riparian areas were an average of 25 m wide (range = 15-100 m). Deer most often selected portions of these riparian areas having from 80-405 aspen trees per ha within the 2.5-15 cm DBH size class and dense multilayered understory vegetation. These areas provide shade and thermal cover, but more importantly hiding cover, particularly for fawns. Understory vegetation typically consisted of several different grass species, aspen shoots, willow, snowberry, wild rose, and corn lily (Veratrum californicum). Willow and snowberry where the most abundant understory species making up 40 and 25 percent of understory vegetation respectively. The overstory canopy in these areas consisted of an average of 282 aspen trees per ha with an average DBH of 23 cm and average heights

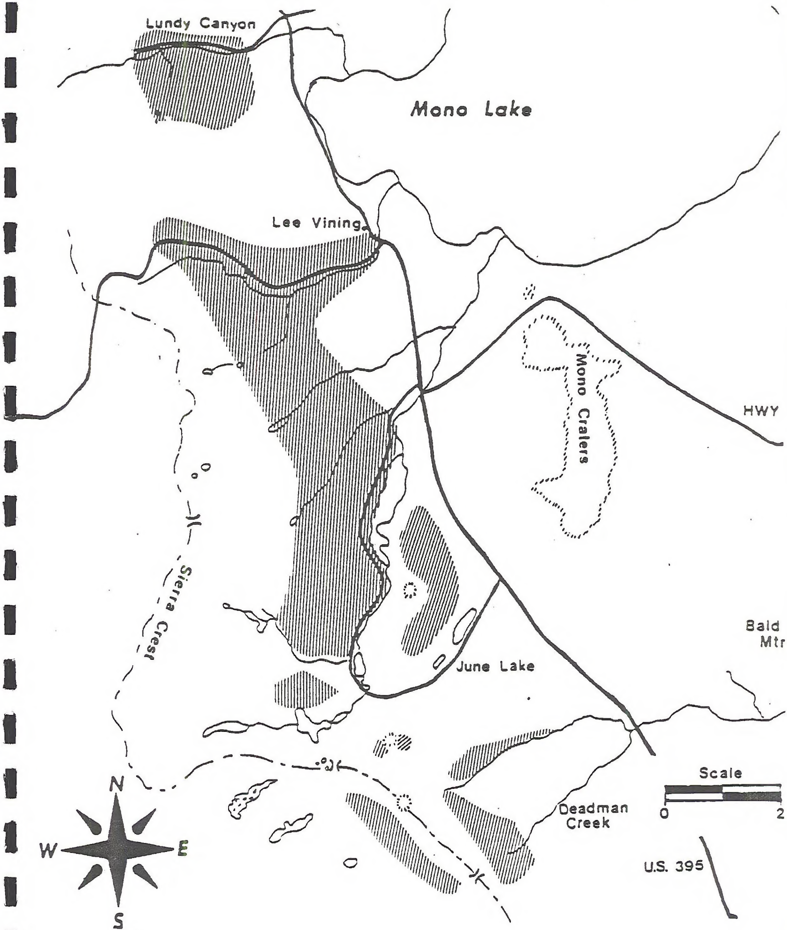
Lundy Canyon
Mono Lake
Lee Vining
Mono Craters
HWY
Sierra Crest
June Lake
Bald Mtr
Scale
0
2
Deadman Creek
U.S. 395
N
W
E
S

Figure 7. Locations of major fawning areas, Casa Diablo deer herd.

of 9 m.

Seven deer had home ranges including mixtures of both meadow and aspen riparian habitat types. Home ranges of these deer typically consisted of a portion of a large aspen grove and nearby associated meadows. All seven deer expanded their home ranges to include nearby Great Basin sagebrush and montane chaparral areas once meadow and aspen understory vegetation began to senesce, in late August of 1986 and in late June of 1987.

Three deer which summered east of Hwy 395 and south and east of Mono Lake had home ranges approximately 2 times larger than those that summered on the east slope of the Sierra Nevada. These does had summer home ranges averaging 384 ha in size which consisted primarily of Jeffrey pine and Great Basin sagebrush habitat types. Limited water distribution throughout the Jeffrey pine habitat type may have caused these does to range over a larger area. One doe, which summered east of Mono Mills (Figure 6), was observed drinking from a sheep watering trough 1.9 km west of the center of her home range. Another doe consistently was observed on her summer home range located approximately 2 km from the nearest water source. These does utilized large, open stands of Jeffrey pine consisting of an average of 243 trees per ha. Understory vegetation consisted primarily of 1-1.5 m high big sagebrush and bitterbrush.

MORTALITIES

Five of the original 23 radio-collared deer (22%) marked during January-March 1986 on the Casa Diablo winter range were killed by mountain lions (Figure 8, Appendix Figure 6). The first, from Truman Meadows, was killed on HA-I on 26 April 1986. Her carcass was found buried under about 5 cm of dirt and litter in a large opening of Great Basin sagebrush. Two does were killed by mountain lions on 29 January 1987 on pinyon-juniper transition range in the Banner Ridge area. Both carcasses, which were found approximately 8 km apart, were mostly consumed and buried at the base of pinyon trees. One doe was killed by a mountain lion on 20 March 1987 on the Blind Spring Hills wintering area. Her carcass, which was buried in a sandy draw, was found to be almost entirely eaten. A fifth doe was killed by a mountain lion while

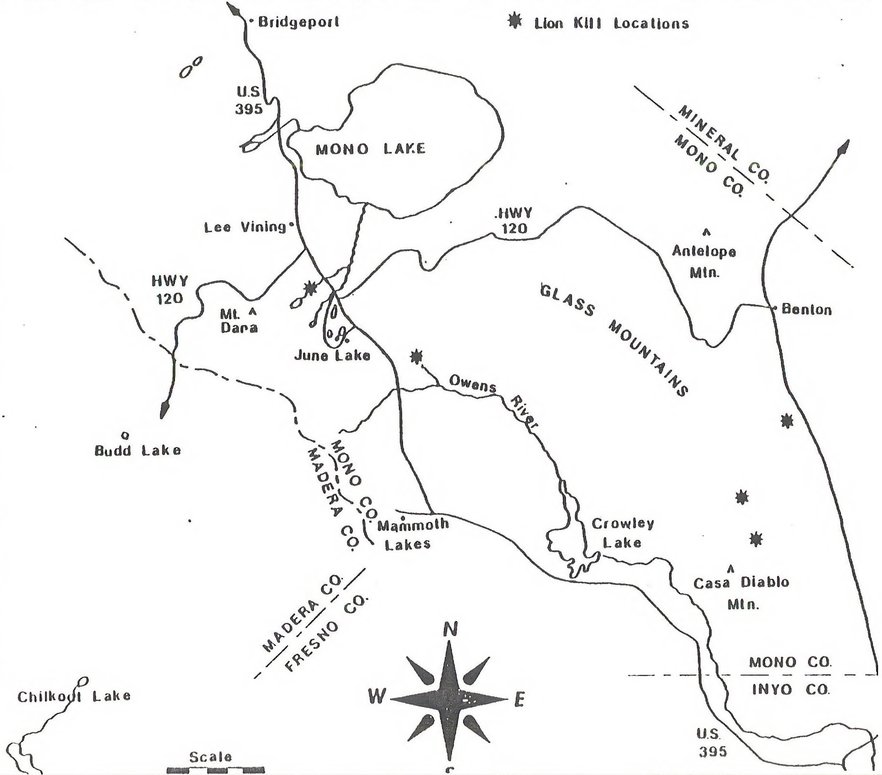
Bridgeport
✸ Lion Kill Locations
U.S. 395
MONO LAKE
MINERAL CO.
MONO CO.
HWY 120
Lee Vining
Antelope Mtn.
HWY 120
GLASS MOUNTAINS
Benton
Mt. Dana
June Lake
Owens River
Budd Lake
MONO CO.
MADERA CO.
Mammoth Lakes
Crowley Lake
Casa Diablo Mtn.
MADERA CO.
FRESNO CO.
N
W
E
MONO CO.
INYO CO.
Chilkoot Lake
U.S. 395
Scale

Figure 8. Locations of five radio-collared does killed by mountain lions.

on her summer range sometime during October 1987. Her carcass was found buried in willows on Parker Creek. Two additional does died while on their summer ranges; the cause of death was undetermined.

DEER HERD COMPOSITION COUNTS

Post season composition counts have been conducted over the last eight years on the Casa Diablo winter range. Fawn:doe ratios have averaged 49:100 and buck:doe ratios 9:100 (Table 2). During this study, post season composition counts were conducted on 7 January 1986, 6 January 1987, and 8 January 1988. In 1988, fawn:doe ratios were the lowest ever recorded (36:100).

Spring composition counts were conducted on the Casa Diablo winter range from the ground in April of 1986 and 1987. In 1986, fawn:doe ratios were 21:100 and 39:100 in 1987.

Deer herd size has been estimated at approximately 1,500 animals over the last several years using a ratio estimation method (Anderson et al. 1974), a technique utilizing annual buck harvest figures and herd composition data.

TABLE 2. Results of Casa Diablo Deer Herd Spring and Fall Composition Counts per 100 Does, 1980-1988

YR	Fall		Fall Sample	Spring	Spring Sample
	Bucks	Fawns		Fawns	
1980-81	13	58	---	47	---
1981-82	10	54	353	50	---
1982-83	7	41	403	28	---
1983-84	8	37	526	46	---
1984-85	7	43	366	42	191
1985-86	15	61	444	21	153
1986-87	6	60	293	39	602
1987-88	6	36	940	--	---

DISCUSSION

MIGRATION CORRIDORS

The Glass Mountains, which extend in a westerly direction from the center of the Casa Diablo winter range, provide a source of orientation for deer as they migrate to and from wintering areas. Two major migration corridors, one along the north slope and one along the south slope of the the Glass Mountains were identified. Twenty-one of 27 radio-collared deer, representing all six subwintering areas, utilized the corridor on the south slope of the Glass Mountains during the spring and fall migrations of 1986 and 1987. It is believed that this corridor is used to such an extent because of its southerly aspect. South aspects typically are the first places to become snowfree in late winter (Garrott et al. 1987). Thus, snow does not appear to form an impediment to migration or to retard spring growth as it often does on the north slope of the Glass Mountains. In addition, this corridor was the shortest and the easiest way for most radio-collared deer to travel to and from wintering areas.

Two radio-collared does, both from the Truman Meadows wintering area, utilized different migration corridors during consecutive spring periods. In 1986, both does migrated along the south slope of the Glass Mountains, but in 1987 both used the north slope. Although the south slope is not the shortest route between winter and summer ranges for deer from Truman Meadows, it is the easiest route offering the most suitable conditions in years of above average snowfall (eg., 1986). In early April of 1986, due to snow free conditions, plant phenology was found to be much in advance and forage availability much greater along the south slope of the Glass Mountains than the north slope. Thus, in 1986 both does took advantage of these conditions by migrating along the south slope. In the dry year of 1987, snow cover on the north slope of the Glass Mountains was much lighter than normal in April, resulting in an earlier thaw and greater forage availability than in 1986. Hence, both does migrated along the north slope where they were able to take advantage of abundant forage while at the same time migrating a shorter distance to their summer ranges.

The fact that both radio-collared does have learned to utilize two migration corridors may be a form of opportunism (Geist 1982). In both cases, these animals were able to take advantage of abundant food sources brought about by ecological and climatic factors.

By traveling along the north slope of the Glass Mountains during the spring of 1987, these does were able to minimize expenditures of energy and nutrients on maintenance by migrating a shorter distance while at the same time maximizing resources for reproduction (Geist 1982).

Radio-collared deer utilized two major migration corridors after departing HA-I. One of these extends to the west around the south slope of White Wing Mountain and over San Joaquin Ridge (Figure 3). Deer crossed San Joaquin Ridge using several passes with the majority of movement confined to Deadman Pass. These passes, located at elevations between 2,960-3,195 m, can be considered as the link between east and west side Sierra seasonal ranges. Assuming that the radioed sample of deer is representative of the entire population, about 200 deer from the Casa Diablo herd cross San Joaquin Ridge to gain access to west side summer ranges. Several hundred deer from another eastern Sierra herd (the Sherwin Grade herd) which winter in Round Valley about 14 km north of Bishop, are also known to cross San Joaquin Ridge to gain access to their west side summer ranges (Kucera, Unpubl.).

Migration between winter and summer ranges of individual radio-collared deer were quite variable. Deer summering west of the Sierra crest were found to migrate as far as 120 km between winter and summer ranges. Those deer summering in the White Mountains had up slope migrations between winter and summer ranges of 1-3 km.

HOLDING AREAS

Deer from the Casa Diablo herd utilized three major holding areas during the spring and fall migrations of 1986 and 1987. Elevational, topographical, and vegetative features of these holding areas are quite similar. All three holding areas are located at approximately the same elevation, between 2,134-2,439 m, and all generally are situated at the base of south and east facing slopes. Vegetative composition on all these holding areas consists of a mixture of Jeffrey pine and Great Basin sagebrush habitat types.

Deer generally occupied holding areas for a longer period during the spring than in the fall. Fourteen deer utilized both HA-I and HA-II in the spring of 1986, and one monitored doe was found to occupy all three holding areas.

Much of the land in which holding areas are located is administered by the United States Forest Service. Therefore, these lands are managed for a variety of different uses including recreation, grazing, and logging. About 15% (4 km) of land in HA-I is in private ownership, most of which includes meadow areas along the Owens River that are used primarily for cattle grazing. A small portion of land at the northern corner of HA-III is also in private ownership where a small subdivision exists.

Winter logging of Jeffrey pine has been conducted over the last several years throughout the south and west portion of HA-I. Logging practices typically have included pre-and post-commercial thinning of trees < 20 cm DBH with an average spacing of 5 m between trees. Thus, many dense pockets of Jeffrey pine which provide the best hiding and escape cover for deer have been eliminated throughout this holding area. Several studies have identified the importance of dense hiding and escape cover for deer, especially during hunting season (Dasmann and Taber 1956, Sweeney et al. 1971). On fall holding areas of the North Kings herd, dense cover is a necessary and major component during hunting season (Bertram and Rempel 1977).

Conversely, thinning of dense stands of Jeffrey pine most likely has increased forage production within thinned areas. According to Ffolliott and Clary (1972), this is an acceptable generalization for most forest types. Other research has also indicated that use by deer commonly increases after logging (Wallmo et al. 1976).

No formal evaluation has been conducted concerning the effects of timber management practices on deer use within east side Sierra Jeffrey pine habitats. Therefore, it is difficult to postulate whether these practices have actually been of benefit to deer. According to Dasmann (1981), there can be too much cover as well as too little. HA-I already contains one large meadow area and vast open areas of Great Basin sagebrush habitat both of which typically provide an abundance of forage. Thus, since forage availability does not appear to be a limiting factor, perhaps it may be of greater benefit to deer if areas of dense Jeffrey pine are maintained.

Throughout most of the Jeffrey pine forest, roads, created primarily for timber harvest have reduced much of the effectiveness of hiding and escape cover by providing easy access to the public. Logging roads have been a major factor contributing to human disturbance on holding areas of the North Kings deer herd (Bertram 1984). Since logging of harvestable timber is conducted only during the winter months, it does not directly conflict with deer use of Jeffrey pine habitats. However, public fuel wood gathering of logging slash and thinned trees are activities which normally coincide with the timing of fall and spring migrations.

SPRING MIGRATION

During the two spring periods studied, little overall variation was found in the overall timing of migration to the summer range (Figure 4). This is despite great extremes in total amounts of snowfall received during the winters of 1985-86 and 1986-87. Garrott et al. (1987) found that the timing of spring migration for deer in Colorado varied annually by as much as 1 month and was related to severity of winter, with deer migrating later after more severe winters. Bertram and Rempel (1977) found migration from the winter range in deer from the North Kings herd to be approximately two weeks earlier following dry winters than winters of normal to above normal precipitation.

In this study, I hypothesize that the consistency in the timing of migration between the two spring periods studied was related to the extreme difference in the severity of winters. Following the wet winter of 1985-86, a heavier than normal snowpack retarded spring growth along the south slope of the Glass Mountains, thus delaying spring migration until early April. After the very dry winter of 1986-87, spring green-up on the winter range did not occur until mid-March due to a lack of mid and late winter precipitation. This was reflected in the movements of 16 deer which moved during March from high elevation transition range to low lying wintering areas where the availability of spring forage was greatest. Deer remained on the winter range until early April when spring green-up at higher elevations along the migration corridor began to occur.

FALL MIGRATION

According to telemetry data, migration to the winter range in fall 1987 was in response to snow storms and the consequent accumulation of snow on the summer range. Snow was also found to be a cause of migration to the winter range in other studies (Dixon 1932, Leopold et al. 1951, Gilbert et al. 1970, Moen 1973, Bertram 1984). Loveless (1964) stated that snow depth appeared to be the major reason for deer moving to lower elevations earlier in some years than others.

Because of near drought conditions in 1987, forage on the summer range became of poor quality by mid-July. As a result, deer did not appear to show a strong affinity to summer range areas once fall snow storms began to occur. Instead, deer migrated to mid-elevational transition range along migration corridors where snow accumulation was less and forage quality greater.

In fall of 1986, migration to the winter range was found not to be correlated with inclement weather simply because only one minor fall storm occurred on 24 September. Accordingly, migration was found to be very gradual occurring over approximately a three month period (24 September 1986-3 January 1987. Ultimately, migration to the winter range in 1986 for deer from the Casa Diablo herd probably was caused by declining forage conditions on the summer range. For deer in Colorado, fall movements were also attributed to declining forage quality on the summer range as well as the availability of higher quality forage on the winter range (Garrott et al. 1987). Because 1986 was a very wet year, forage quality on the summer range remained high for a longer period then it would during normal years. Thus, deer showed a greater affinity for summer range areas, as illustrated by the gradual dispersal of radio-collared deer from the summer range.

WINTER RANGE

During the winter of 1986-87, 20 of 23 radio-collared deer returned to the same locations where they were marked on the winter range. However, three radio-collared does never returned to the Casa Diablo Mountain wintering area where they were marked in January of 1986. Two of these does occupied pinyon-juniper transition range between 8-12 km northwest of the Casa Diablo Mountain throughout the entire winter. A third wintered near Sagehen Peak, located on the north side of the Glass Mountains approximately 33 km northwest of Casa Diablo Mountain.

To my knowledge, very little data has been published which documents a lack of fidelity in migratory deer to specific wintering or summering areas. Robinette (1966) cited two instances of belled deer which were found to occupy different summer home ranges during consecutive years. The observed behavior of these three Casa Diablo deer may best be explained by elevational, topographical, and vegetational similarities between the Casa Diablo Mountain wintering area and pinyon-juniper transition range. Why should deer expend extra energy by migrating a further distance to an area that offers similar or perhaps less forage quality and availability? This may be interpreted as another form of opportunism as throughout the winter of 1986-87 deer on transition range were found to feed extensively on an abundant crop of pinyon pine nuts which were made readily available because of below normal snow accumulations. Thus, deer were able to minimize energy expenditures on maintenance by remaining on transition range where resources were of higher density and quality (Geist 1981). As a result deer were able to maintain a high level of nutrition throughout the winter months. This in turn culminated in better animal condition, and thus higher pregnancy and fetal rates among adult does collected on transition ranges (Taylor, Unpubl.).

Throughout much of the Casa Diablo winter range, water appears to be a major factor limiting deer distribution during winter months when succulent forage or snow is unavailable. When available, succulent forage and snow can provide enough water to meet metabolic needs, but free water is required during other times (Wallmo 1981, Dasmann 1981). Portions of the Casa Diablo winter range having limited water availability, such as Chidago Flat and Black Rock, where found to have large areas of seemingly suitable habitat which where virtually devoid of deer.

Water and forage appear to be the primary factors governing the size of winter home ranges. Deer occupying pinyon-juniper transition range had home ranges 2 times larger than deer which utilized other habitat types on low lying wintering areas. On transition range free water was readily available from numerous streams and seeps and, therefore, provided increased opportunity for selective foraging. Thus, deer were able to forage throughout larger areas in search of pinyon nuts and other more desirable plant species. On the North Kings winter range deer occupying Foothill-Woodland types were found to have a slightly larger home range than deer in more diverse habitat types. However, this difference was attributed to cover distribution and its relation to forage and water (Bertram 1984). Throughout most of the lower winter range, such as Marble Creek, water distribution is more limited during certain periods and appears to directly influence the size of winter home ranges. This is especially true during October and November when the majority of deer use appears to be concentrated within 1.2 km of water.

The 1987, post-season composition counts conducted on the winter range in January, 1988 revealed the lowest fawn:doe ratios ever recorded for the Casa Diablo herd (36:100). This likely is related to the indirect effects of precipitation on forage quality and quantity on the summer range (Connolly 1981). Because 1987 was one of the driest years on record in the eastern Sierra, the quality and availability of preferred forages on the summer range probably declined much earlier than in years of normal precipitation. As a result, fawns were in relatively poor condition when they arrived on the winter range. This was determined subjectively by examining femur bone marrow of 11 road killed fawns (Cheatum 1949). Deer typically accumulate body fat during summer and fall after productive functions generally have been satisfied. If deer cannot obtain high level of quality foods on summer and intermediate ranges during early fall, production of body fat will be diminished. Therefore, deer with limited fat reserves, such as fawns and adult deer from poor quality summer range, will succumb more readily while on the winter range once sufficient energy no longer is present for maintaining bodily functions (Short 1981).

A total of 5 radio-collared deer, 22% of the original radioed sample were killed by mountain lions between 22 April 1986 and 26 March 1987. Lion predation may under certain conditions act to limit prey populations (Hornocker 1976). Because no objective data exists concerning lion-deer relationships on range occupied by the Casa Diablo herd, one can only speculate as to the effects of lion predation on this population.

SUMMER RANGE

Provided the telemetered sample of deer is representative of the entire population and that herd size estimations are fairly accurate, 75% of the Casa Diablo herd summers on the east slope of the Sierra Nevada. Thus, about 1,100 animals occupy summer range east of the Sierra crest throughout south and west-central Mono County, between Mammoth Lakes and Bridgeport.

Telemetry data also indicate that nearly 70% of the Casa Diablo deer herd, some 1,000 animals, summer north of the original administrative boundaries established for the herd by DFG. Therefore, since most all bucks are harvested on the summer range, it is likely that buck kill totals compiled each year for the Casa Diablo herd do not represent the actual number of bucks harvested from the herd. This is supported by the fact that four ear tagged bucks were killed by hunters within the administrative boundaries of the Mono Lake herd. Had these deer not been marked, they would have been included as part of the total kill for the Mono Lake herd. Since the Casa Diablo and Mono Lake herds are thought to share summer range together, it virtually is impossible to determine the true buck harvest for each herd. Consequently, herd size estimations based in part on buck harvest figures become questionable.

Recent changes in buck harvest management strategies in Mono County by DFG has resulted in the split of hunting zone X-9 into zones X-9a and X-9b. Prior to this split, three and possibly four herds in Mono County occupied summer range within the boundaries designated for zone X-9. From telemetry data, it was possible to delineate distinct summer range boundaries for the Casa Diablo herd which were recognizable from those of the Sherwin herd to the south and the East Walker herd to the north. These delineations were used for the purpose of demarcating new zone boundaries which now allow DFG to manage the Casa Diablo and Mono Lake herds as one in zone X-9a.

Radio-collared deer exhibited strong fidelity to individual summer ranges. All occupied the same summer home range in 1987 as in 1986. Others, (Ashcraft 1961, Gruell and Papez 1963, Robinette 1963, Schneegas and Franklin 1972, Bertram 1984, Loft et al. 1984, Garrott et al. 1987), have also reported that deer consistently use the same specific summer range, winter range, and migration routes.

One radio-collared doe was found to shift home ranges after her original one was subjected to heavy use by domestic sheep. The summer home range of this particular doe originally was centered on a small riparian strip near the lower north end of Parker Bench. She arrived on this summer range on 1 May 1987 and was observed several times there until sheep entered the area on 2 July. She immediately abandoned this home range and moved approximately one mile west to an adjacent riparian strip where she remained for the rest of the summer. Similar shifts of home range resulting from destruction of food and cover have also been documented by Robinette (1966).

One other monitored doe which summered in Jeffrey pine habitat was found to shift her home range during early August for two consecutive years. She moved from her original summer home range, which was located in Jeffrey pine forest, to an area devoid of trees that consisted mainly of 1-1.5 m high bitterbrush and sagebrush. This dispersal was apparently done in order to establish a new home range with closer proximity to water and perhaps more adequate fawn hiding cover (Robinette (1966).

Deer occupying summer range in Jeffrey pine habitat had home ranges slightly larger than deer in other habitats. Again, this may be related to water and its proximity to forage and cover. Pumice soils associated with Jeffrey pine forest on the east side of the Sierra generally hold very little water. This is especially true of areas immediately south and east of Mono Lake, where two monitored does summered. These deer were observed to travel several km on a daily basis between feeding and resting, and watering locations.

Water is very likely a factor limiting deer distribution and numbers throughout much of the Jeffrey pine habitat type, especially after spring growth has desiccated. It also may influence fawn survivability since fawns, which have a greater relative metabolic rate, probably are more sensitive to water deprivation and consequently succumb more quickly to this form of stress than do adult deer (Short 1981).

Undoubtedly, the major reason for deer from the Casa Diablo herd showing such affinity for the east slope of the Sierra Nevada is that it offers the best suitable habitat and conditions for fawning.
Aspen-riparian habitat was the type most often utilized by radio-collared does summering on the east slope of the Sierra. This type is preferred because dense understory vegetation provides important thermal and hiding cover, especially for fawns (Reynolds 1969, Loft et al. 1987). It also is preferred because of its close proximity to water and the succulent forage which it provides (Kauffman and Krueger 1984, Loft et al. 1986).

It is estimated that riparian habitats encompass approximately 14,97 ha or 2% of all lands on the Inyo National Forest. Seventy percent of these riparian habitats (10,522 ha) are comprised of wet meadows above 2,440 m (USDA 1987). The fact that 93% of all radio-collared deer summering on the east slope of the Sierra utilized this habitat type, one which comprises a relatively small portion of the total summer range, may indicate that this type is actively selected for by deer.

Livestock grazing occurs on an annual basis throughout most state and federal lands on the east side of the Sierra. Sheep grazing is particularly prevalent throughout most east side summer range habitats occupied by the Casa Diablo deer herd. This is especially true of lands owned by the Los Angeles Department of Water and Power, which mostly are comprised of meadow and aspen-riparian habitats. Direct conflicts in the timing of sheep and deer use occur during both spring and summer periods in many aspen-riparian areas, especially on HA-II and other lands located on the east slope of the Sierra. In those aspen-riparian habitats that have received heavy sheep use on an annual basis, much of the understory vegetation has been severely reduced from grazing and trampling. This, in turn, has affected regeneration and survival of young trees (Loft et al. 1987).

RECOMMENDATIONS

Since seasonal habitats and migration routes utilized by the Casa Diablo deer herd have now been delineated, it is important to maintain and enhance, if possible, the quality of these areas in order to achieve herd management objectives outlined in the Casa Diablo Herd Management Plan (Thomas 1984). Therefore, to assist wildlife and habitat managers in this endeavor some general recommendations regarding habitat maintenance and manipulation of critical use areas are in order.

Holding areas are utilized for up to 6 weeks during both spring and fall migration and therefore efforts should be made to attain adequate high quality forage and cover during these times. Livestock grazing occurs on on all holding areas identified and the location and use periods of some allotments suggest the probability of conflict with deer, especially during spring migration. Thus, the timing and intensity of livestock grazing should be evaluated and provisions made which minimize competition for available forage.

Timber harvest and thinning can have beneficial effects on deer forage production by opening the canopy and stimulating herbaceous growth and browse production. However, thinning of Jeffrey pine forest has eliminated valuable hiding and escape cover, which appear to be of particular importance during the fall. Therefore, it is essential that dense stands of Jeffrey pine be maintained especially on fall holding areas where deer are dependent on this habitat type for cover.

A dense network of logging roads throughout most of the Jeffrey pine forest has reduced much of the effectiveness of this habitat type as hiding and escape cover by increasing accessibility and disturbance to deer. Thus, a program of road closure and rehabilitation is needed to improve habitat conditions and reduce human disturbance throughout areas impacted by past timber harvests.

Water is scarce and poorly distributed throughout much of the Casa Diablo winter range and portions of the summer range, especially in Jeffrey pine and Great Basin sagebrush habitats to the south and east of Mono Lake. As a result, deer use generally is restricted to favorable habitats near permanent water sources. In order to increase deer densities on a herd wide basis, a major management objective of the Casa Diablo herd, it is essential that permanent water sources be developed in unwatered areas. This can be achieved by improving existing water sources and establishing windmills and rainwater collectors, or "guzzlers" (Appendix Figures 7a, 7b, and 8).

Three radio-collared deer occupied summer range on the west side of the Sierra Nevada. These animals were provided access to their west side summer ranges by a migration corridor extending around the south slope of White-Wing Mountain and over San Joaquin Ridge. White Wing Mountain and San Joaquin Ridge have been proposed for nordic ski development in phases IV and V of the Mammoth-June Mountain Ski Area Development Plan. It is essential, if ski development is allowed to occur, that development be intelligently planned when considering the placement of proposed facilities within this migration corridor. Thus, it will be necessary to design studies that would gather more site-specific information regarding deer migration and summer use within areas of proposed ski development. It also is imperative that mitigation be designed that will limit human disturbances associated with such developments during migration periods. For example, this may entail reduction or complete cessation of ski area construction and maintenance activities until migration has been completed. It may also include stringent laws that help to prevent free roaming dogs, a typical problem associated with such developments, from harassing migrating deer.

Other areas of the Casa Diablo deer herd range are the subject of land use proposals which may impact deer habitat. A major geothermal power plant has been proposed near the Inyo Craters. One such plant exists and several others are proposed for the Casa Diablo Hot Springs area. In addition, there is a proposal for a major resort complex on Doe Ridge near the Mammoth-June Lake Airport. Several hydropower projects exist or are proposed on drainages between June Lake and Bridgeport, some in critical deer habitat. This study has revealed that deer from the Casa Diablo herd use these areas as migration and summer habitats. The effects of these or other projects will depend on the number developed, and where and how they are developed. Therefore, in order to insure the welfare of the Casa Diablo herd it is imperative to evaluate the effects of land use projects on an individual and a cumulative basis.

Since the Casa Diablo and Mono Lake herds essentially have overlapping summer ranges, it may be biologically and administratively sound to designate these herds as one, e.g., the Mono Lake herd. Future telemetry research of the Mono Lake herd will further clarify this issue.

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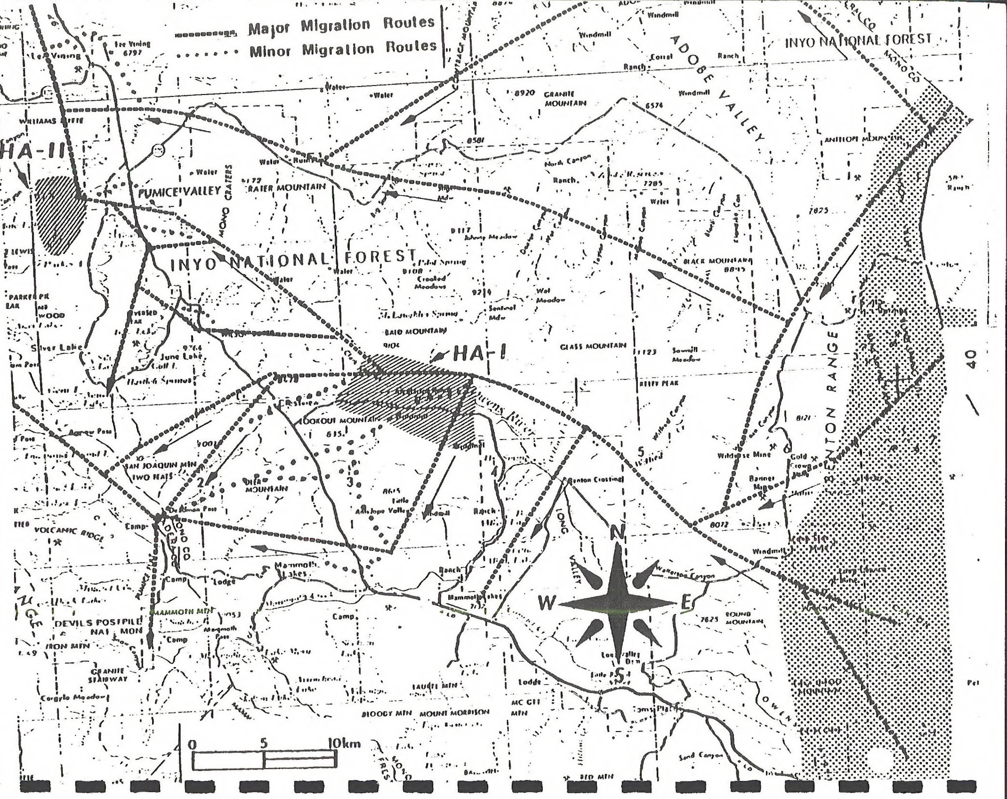
Major Migration Routes
Minor Migration Routes
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HA-I
WILLIAMS BUTTE
PUMICE VALLEY
MONO CRATERS
CRATER MOUNTAIN
INYO NATIONAL FOREST
BALD MOUNTAIN
GLASS MOUNTAIN
BLACK MOUNTAIN
BENTON RANGE
LOOKOUT MOUNTAIN
SAN JOAQUIN MTN
TWO TEATS
DEER MOUNTAIN
VOLCANIC RIDGE
Mammoth Lakes
MAMMOTH MTN
DEVILS POSTPILE NAT MON
IRON MTN
GRANITE STAIRWAY
BLOODY MTN
MOUNT MORRISON
MC GEE MTN
ROUND MOUNTAIN
LONG VALLEY
Benton Crossing
Wildrose Mine
Banner Mine
June Lake
Silver Lake
Lee Vining
Tom's Place
Sand Canyon
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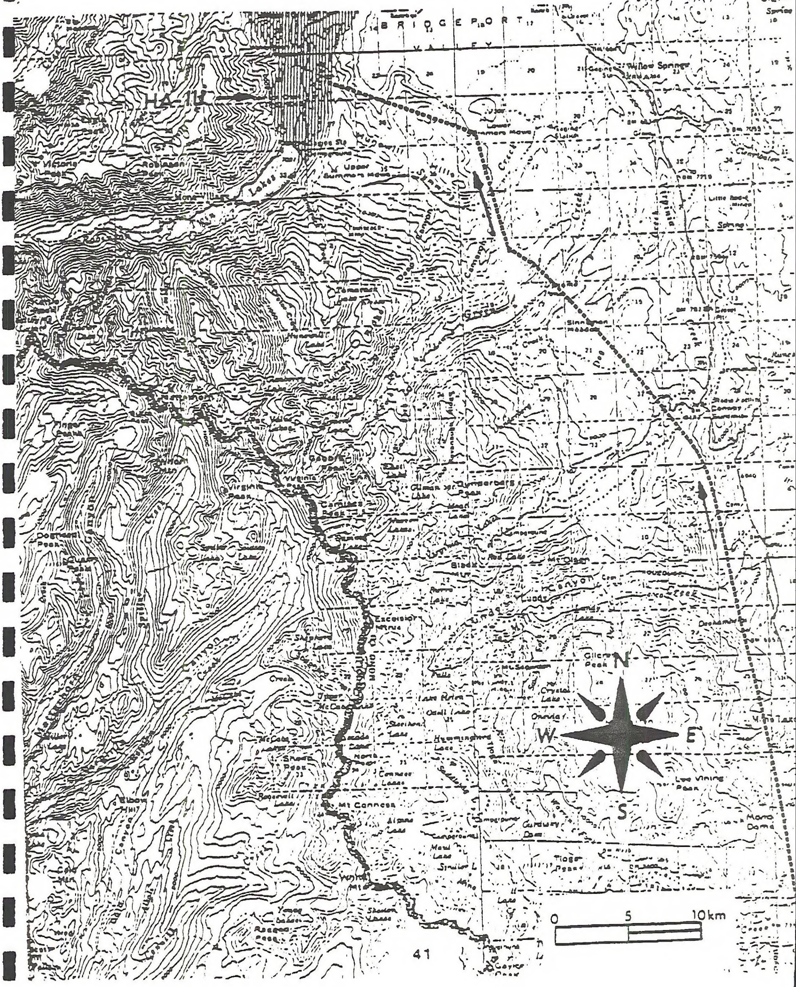
Appendix Figure 1a   Locations of migration routes in
the Casa Diablo deer herd.

Appendix Figure [illegible] [illegible]
the Casa Diablo deer herd.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HA-11
Willow Springs
Lower Summers Mdws
Upper Summers Mdws
Robinson Peak
Victoria Peak
Twin Lakes
Mono Village
Sinnamon Meadow
Green Creek
Dog Creek
Virginia Creek
Matterhorn Peak
Finger Peaks
Virginia Peak
Dunderberg Peak
Gilman Lake
Camiaca Peak
Black Mtn
Excelsior Mtn
Shepherd Lake
Upper McCabe Lake
McCabe Lakes
Lundy Canyon
Mt Olsen
Lundy Lake
Gilcrest Peak
Mt Scowden
Crystal Lake
Lake Helen
Odell Lake
Hummingbird Lake
Shamrock Lake
Greenstone Lake
Conness Lakes
Roosevelt Lake
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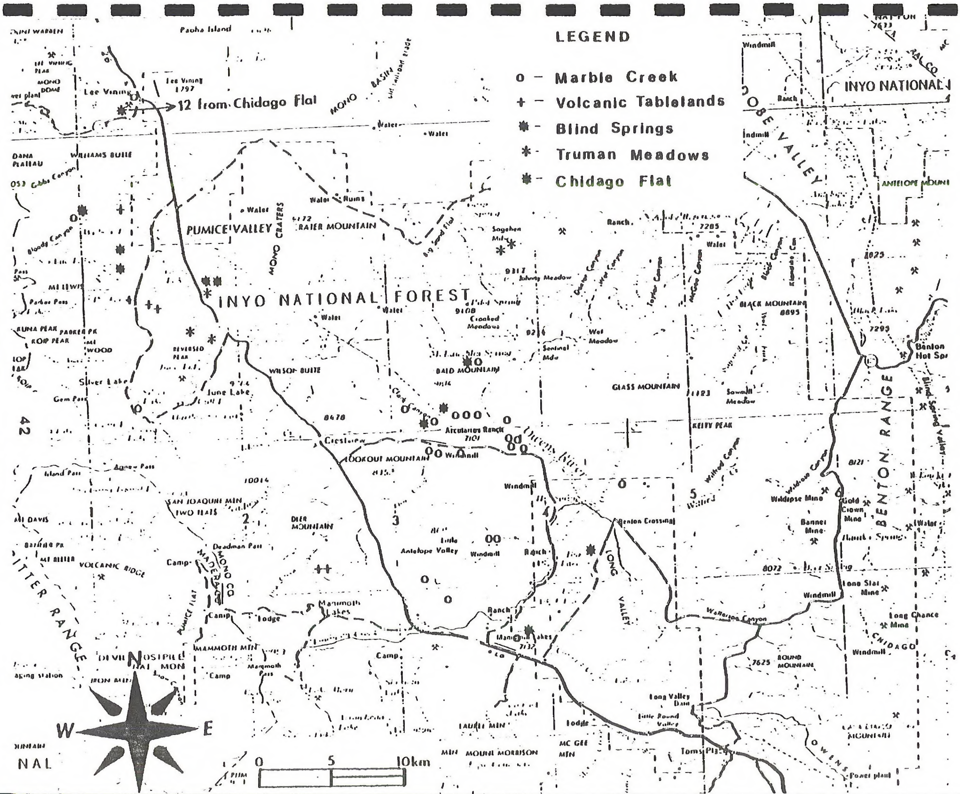
LEGEND
o – Marble Creek
+ – Volcanic Tablelands
✱ – Blind Springs
* – Truman Meadows
✱ – Chidago Flat
12 from Chidago Flat
INYO NATIONAL FOREST
INYO NATIONAL
PUMICE VALLEY
MONO CRATERS
MONO BASIN
Lee Vining
Paoha Island
Williams Butte
Reversed Peak
June Lake
Silver Lake
Wilson Butte
Bald Mountain
Crater Mountain
Sagehen Mdw
Johnny Meadow
Crooked Meadows
Wet Meadow
Sentinel Mdw
Glass Mountain
Black Mountain
Sawmill Meadow
Kelty Peak
Arcularius Ranch
Owens River
Crestview
Lookout Mountain
Little Antelope Valley
Windmill
Ranch
Benton Crossing
LONG VALLEY
Wildrose Mine
Gold Crown Mine
Banner Mine
BENTON RANGE
Benton Hot Spr
Blind Spring Valley
ADOBE VALLEY
Antelope Mount
Lone Star Mine
Long Chance Mine
CHIDAGO
Watterson Canyon
Round Mountain
Long Valley Dam
Little Round Valley
Toms Place
Power plant
OWENS
Mammoth Lakes
Mammoth Mtn
Mammoth Pass
Devils Postpile Nat Mon
Deadman Pass
San Joaquin Mtn
Two Teats
Deer Mountain
Volcanic Ridge
Mono Co
Madera Co
Pumice Flat
Mt Ritter
Ritter Range
Agnew Pass
Island Pass
Gem Pass
Mt Lewis
Parker Pass
Parker Pk
Kuna Peak
Koip Peak
Mt Wood
Dana Plateau
Gibbs Canyon
Bloody Canyon
Laurel Mtn
Mount Morrison
Mc Gee Mtn
Mt Davis
Banner Pk
Iron Mtn
Camp
Lodge
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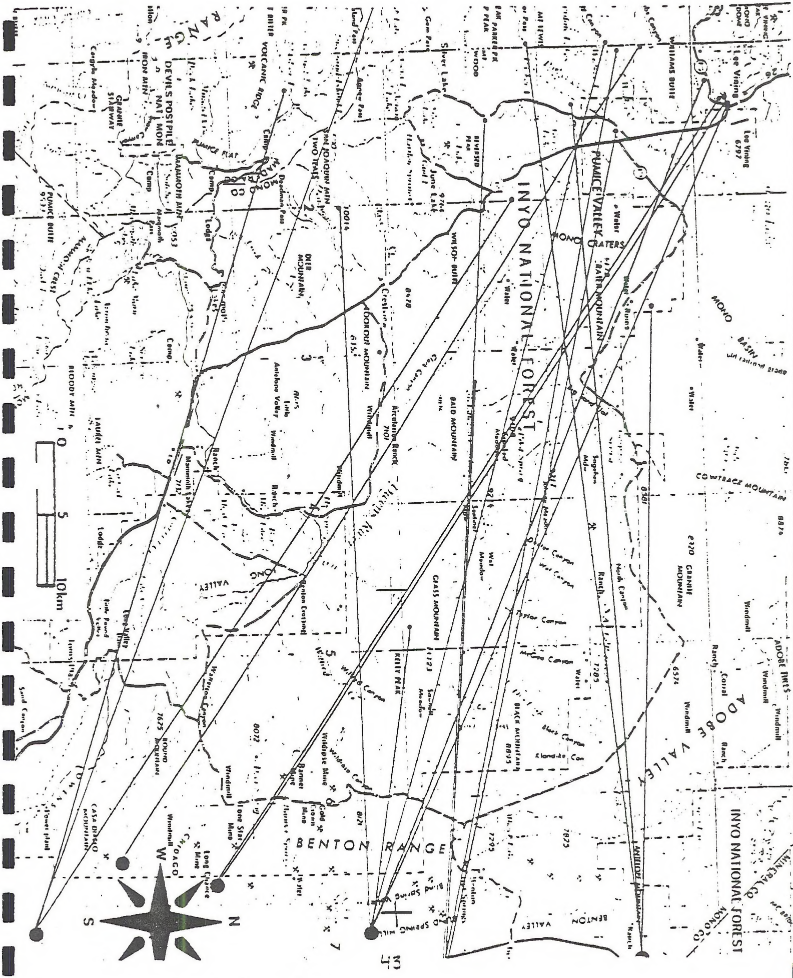
west of the Casa Diablo winter range during the
spring and fall migrations of 1986 and 1987, and the
summers of 1986 and 1987

areas (large circles) and subsequently located on the summer range (small circles).


Lee Vining
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MONO BASIN
MONO CRATERS
PUMICE VALLEY
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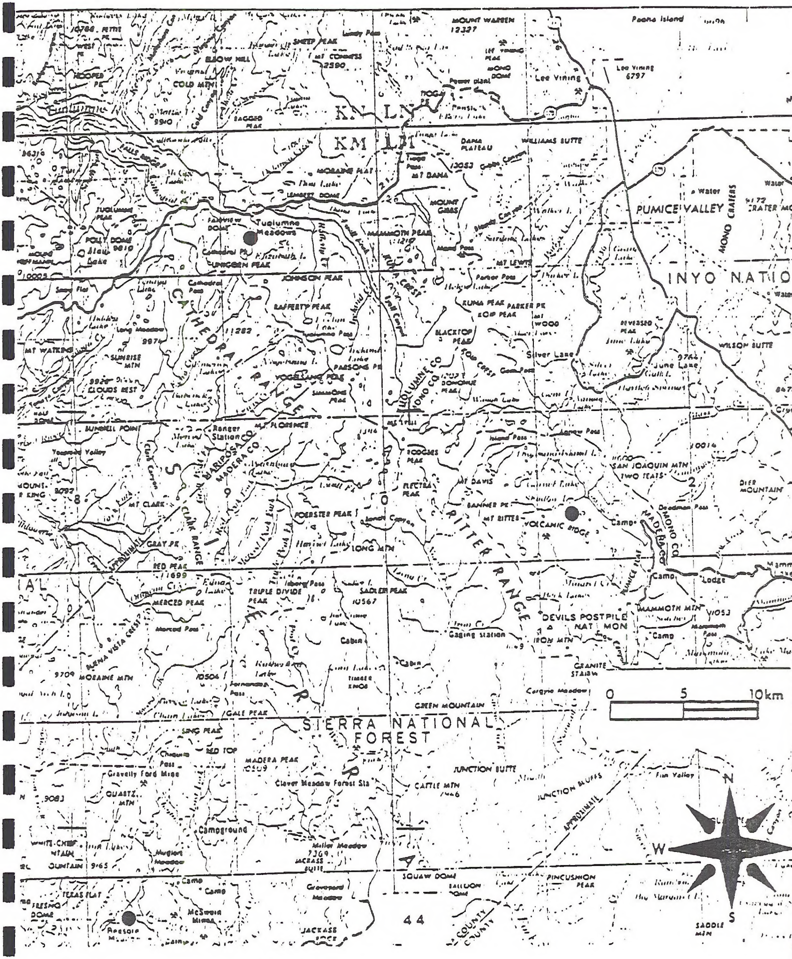
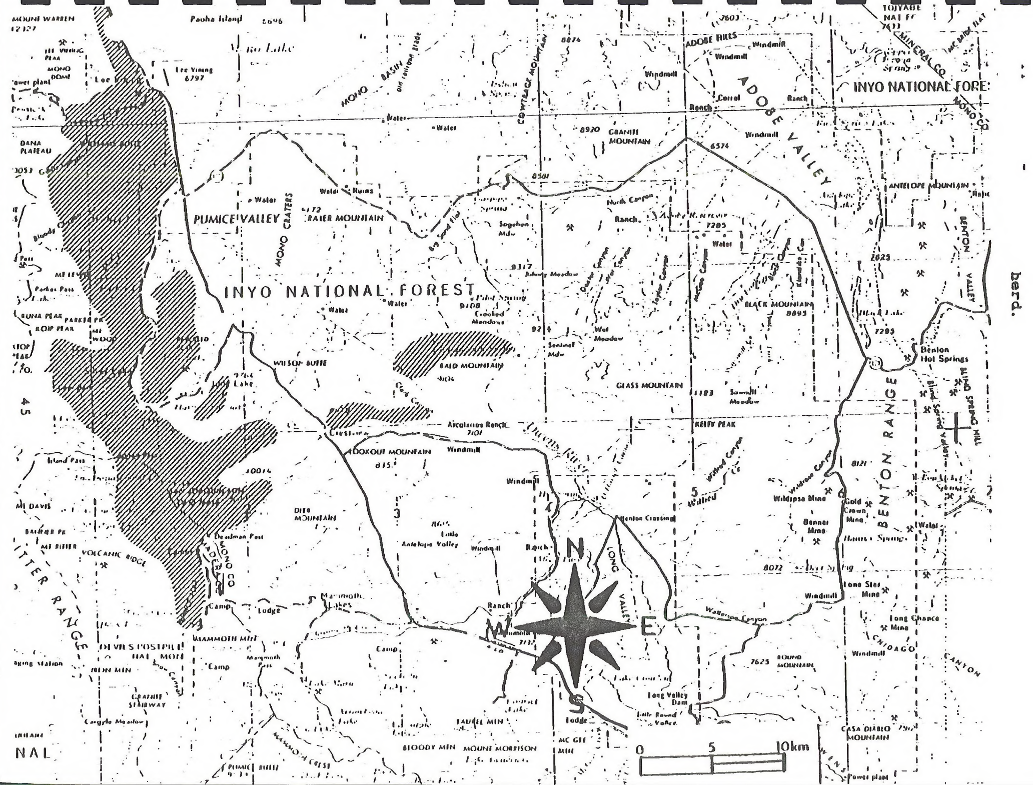
ADOBE VALLEY
ADOBE HILLS
GRANITE MOUNTAIN
COWTRACK MOUNTAIN
ANTELOPE MOUNTAIN
BENTON VALLEY
MINERAL CO
MONO CO
WILLIAMS BUTTE
June Lake
Silver Lake
REVERSED PEAK
WILSON BUTTE
BALD MOUNTAIN
GLASS MOUNTAIN
BLACK MOUNTAIN 8895
KELLY PEAK
Sagehen Mdw
Sentinel Mdw
Wet Meadow
Sawmill Meadow
Arcularius Ranch 7101
LOOKOUT MOUNTAIN
Crestview
Owens River
SAN JOAQUIN MTN
TWO TEATS
DEER MOUNTAIN
Little Antelope Valley
Deadman Pass
VOLCANIC RIDGE
PUMICE FLAT
DEVILS POSTPILE NAT MON
MAMMOTH MTN
IRON MTN
GRANITE STAIRWAY
Mammoth Lakes 7132
LAUREL MTN
BLOODY MTN
PUMICE BUTTE
MAMMOTH CREST
Benton Crossing
LONG VALLEY
Long Valley Dam
Little Round Valley
ROUND MOUNTAIN 7675
CASA DIABLO MOUNTAIN
Wildrose Mine
Banner Mine
Gold Crown Mine
Lone Star Mine
Long Chance Mine
CHICAGO
BENTON RANGE
Benton Hot Springs
Power plant
Sand Canyon
2
3
4
5
6
7
N
S
W
0
5
10km

Appendix Figure 4 Summer range locations of three radio-collared does west of the Sierra crest, Casa Diablo deer herd.


MOUNT WARREN
12327
Paoha Island
SHEEP PEAK
MT CONNESS
12590
ELBOW HILL
COLD MTN
HOOPER PK
9940
RAGGED PEAK
TIOGA PK
LEE VINING PEAK
MONO DOME
Power plant
Lee Vining
Lee Vining
6797
K
L
KM
LM
DANA PLATEAU
WILLIAMS BUTTE
MORAINE FLAT
MT DANA
13053
LEMBERT DOME
MOUNT GIBBS
PUMICE VALLEY
MONO CRATERS
Water
CRATER MO
TUOLUMNE PEAK
FAIRVIEW DOME
Tuolumne Meadows
POLLY DOME
MAMMOTH PEAK
Mono Pass
UNICORN PEAK
Cathedral Pk
MT LEWIS
Parker Pass
INYO NATIO
10005
Cathedral Pass
JOHNSON PEAK
RAFFERTY PEAK
KUNA PEAK
PARKER PK
KOIP PEAK
WOOD
REVERSED PEAK
June Lake
WILSON BUTTE
Long Meadow
9976
11282
BLACKTOP PEAK
MT WATKINS
SUNRISE MTN
PARSONS PK
KOIP CREST
Silver Lake
Gem Pass
9764
June Lake
9926
CLOUDS REST
CATHEDRAL RANGE
VOGELSANG PEAK
SIMMONS PEAK
TUOLUMNE CO
MONO CO
DONOHUE PEAK
SUNRISE POINT
Ranger Station
MT FLORENCE
MT LYELL
Agnew Pass
10016
Yosemite Valley
MARIPOSA CO
MADERA CO
RODGERS PEAK
Island Pass
SAN JOAQUIN MTN
TWO TEATS
DEER MOUNTAIN
9092
MT CLARK
ELECTRA PEAK
MT DAVIS
2
8
5
9
0
BANNER PK
MT RITTER
Deadman Pass
CLARK RANGE
FOERSTER PEAK
VOLCANIC RIDGE
Camp
MADERA CO
MONO CO
GRAY PK
LONG MTN
RITTER RANGE
RED PEAK
11699
Camp
Lodge
MERCED PEAK
TRIPLE DIVIDE PEAK
SADLER PEAK
10567
PUMICE FLAT
MAMMOTH MTN
11053
Merced Pass
DEVILS POSTPILE NAT MON
BUENA VISTA CREST
Gaging station
IRON MTN
Camp
Cabin
Cabin
9709
MORAINE MTN
10504
TIMBER KNOB
GRANITE STAIRW
Fernandez Pass
Corral Meadow
0
5
10km
GALE PEAK
GREEN MOUNTAIN
SIERRA NATIONAL FOREST
SING PEAK
RED TOP
MADERA PEAK
10509
JUNCTION BUTTE
Gravelly Ford Mine
Clover Meadow Forest Sta
CATTLE MTN
JUNCTION BLUFFS
Fish Valley
N
9083
QUARTZ MTN
APPROXIMATE
Campground
W
WHITE CHIEF MTN
Miller Meadow
7369
JACKASS BUTTE
FOUNTAIN 9165
SQUAW DOME
PINCUSHION PEAK
Camp
Camp
BALLOON DOME
TEXAS FLAT
Graveyard Meadow
FRESNO DOME
McSwain Mines
JACKASS
Beasore
COUNTY
COUNTY
SADDLE MTN
S


MOUNT WARREN
Paoha Island
Lee Vining 6797
MONO BASIN
COWTRACK MOUNTAIN
ADOBE HILLS
Windmill
ADOBE VALLEY
MINERAL CO
MONO CO
INYO NATIONAL FORE
Corral
Ranch
Water
GRANITE MOUNTAIN
8920
6574
DANA PLATEAU
PUMICE VALLEY
MONO CRATERS
Ruins
North Canyon
ANTELOPE MOUNTAIN
BENTON
INYO NATIONAL FOREST
Sagehen Mdw
Johnny Meadow
9317
BLACK MOUNTAIN 8895
Crooked Meadows
9108
Wet Meadow
Sentinel Mdw
7295
Benton Hot Springs
WILSON BUTTE
BALD MOUNTAIN
GLASS MOUNTAIN
Sawmill Meadow
BENTON RANGE
Crestview
Alcolarius Ranch 7101
KELTY PEAK
LOOKOUT MOUNTAIN
Windmill
Wildrose Canyon
Wildrose Mine
Gold Crown Mine
Benner Mine
MT DAVIS
VOLCANIC RIDGE
DEER MOUNTAIN
Little Antelope Valley
Benton Crossing
LONG VALLEY
Deadman Pass
MONO CO
Ranch
Lone Star Mine
Mammoth Lakes
Camp
Lodge
MAMMOTH MTN
DEVILS POSTPILE
Long Chance Mine
CHIDAGO CANYON
7625 ROUND MOUNTAIN
Long Valley Dam
Little Round Valley
GRANITE STAIRWAY
LAUREL MTN
MC GEE MTN
BLOODY MTN
MOUNT MORRISON
CASA DIABLO MOUNTAIN
MAMMOTH CREST
Power plant
N
E
S
W
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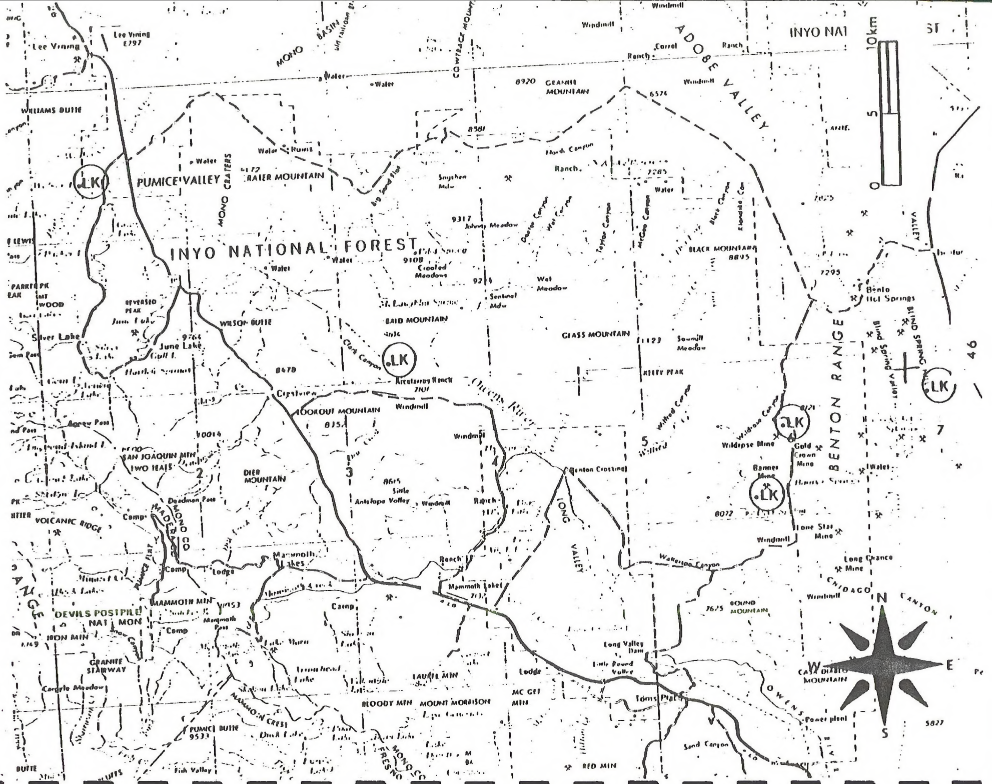
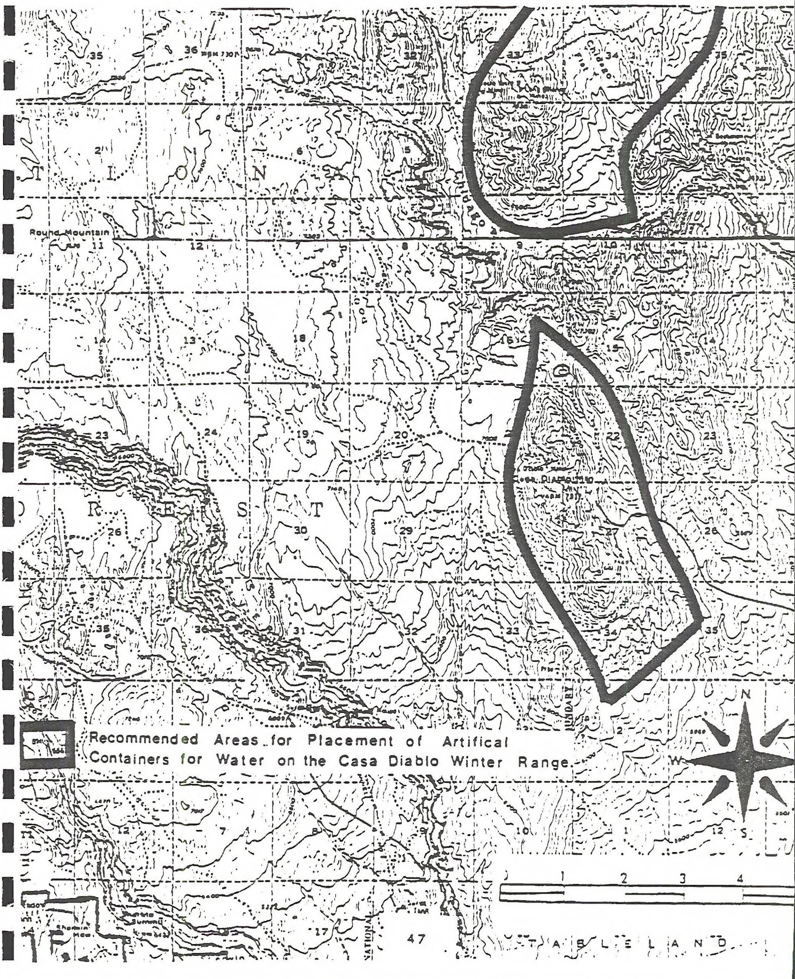
10km
berd.


Lee Vining
Lee Vining
6797
MONO BASIN
MONO
COWTRACK MOUNTAIN
ADOBE VALLEY
INYO NATIONAL FOREST
10km
5
0
Windmill
Corral
Ranch
Water
WILLIAMS BUTTE
LK
PUMICE VALLEY
MONO CRATERS
CRATER MOUNTAIN
Ruins
8920 GRANITE MOUNTAIN
6374
8581
North Canyon
Ranch
7285
Johnny Meadow
9317
Dexter Canyon
Wet Canyon
Taylor Canyon
McGee Canyon
Black Canyon
7025
BLACK MOUNTAIN
8895
7295
Benton Hot Springs
VALLEY
INYO NATIONAL FOREST
9108
Crooked Meadows
Wet Meadow
Sentinel Mdw
BALD MOUNTAIN
GLASS MOUNTAIN
Sawmill Meadow
KELTY PEAK
Clark Canyon
LK
Owens River
8470
Crestview
LOOKOUT MOUNTAIN
8352
Windmill
REVERSED PEAK
June Lake
Gull L.
Silver Lake
WILSON BUTTE
Agnew Pass
SAN JOAQUIN MTN
TWO TEATS
DEER MOUNTAIN
2
3
4
5
6
7
46
Little Antelope Valley
Windmill
Ranch
Benton Crossing
LONG VALLEY
Wildrose Canyon
LK
Wildrose Mine
Gold Crown Mine
Banner Mine
LK
BENTON RANGE
Blind Spring
LK
Lone Star Mine
Windmill
Watterson Canyon
Long Chance Mine
CHIDAGO CANYON
Windmill
7675 ROUND MOUNTAIN
N
W
E
S
CASA DIABLO MOUNTAIN
OWENS
Power plant
5827
Deadman Pass
VOLCANIC RIDGE
MADERA
MONO CO
Camp
Lodge
Mammoth Lakes
Ranch
Mammoth Lakes
DEVILS POSTPILE NAT MON
MAMMOTH MTN
Mammoth Pass
IRON MTN
GRANITE STAIRWAY
Cargyle Meadow
Long Valley Dam
Little Round Valley
Lodge
Toms Place
LAUREL MTN
BLOODY MTN
MOUNT MORRISON
MC GEE MTN
PUMICE BUTTE
9533
MAMMOTH CREST
FRESNO
MONO CO
Fish Valley
RED MTN
Sand Canyon

lions, Casa Diablo deer herd.

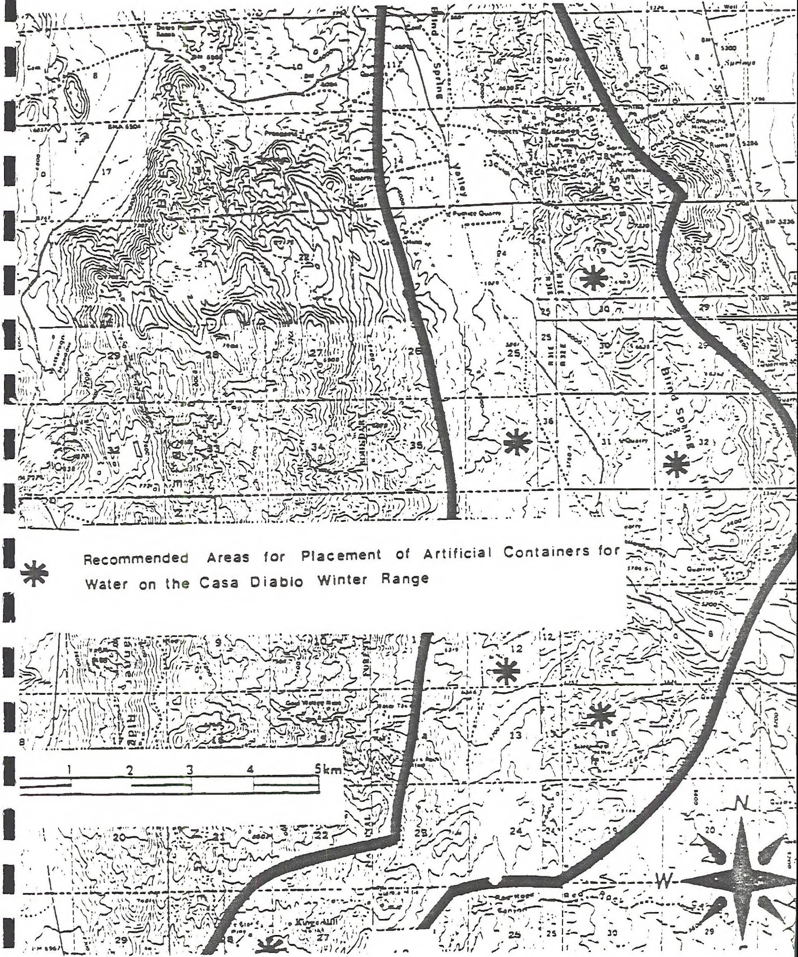
establishment of rainwater collectors and guzzlers necessary for providing permanent water.



Recommended Areas for Placement of Artifical Containers for Water on the Casa Diablo Winter Range.

Round Mountain
35
36
32
33
34
2
6
5
3
11
12
7
8
9
10
14
13
18
17
16
15
23
24
19
20
22
26
30
29
27
31
DIABLO
T
O
N
R
E
S
T
TABLELAND
N
W
S
0
1
2
3
4

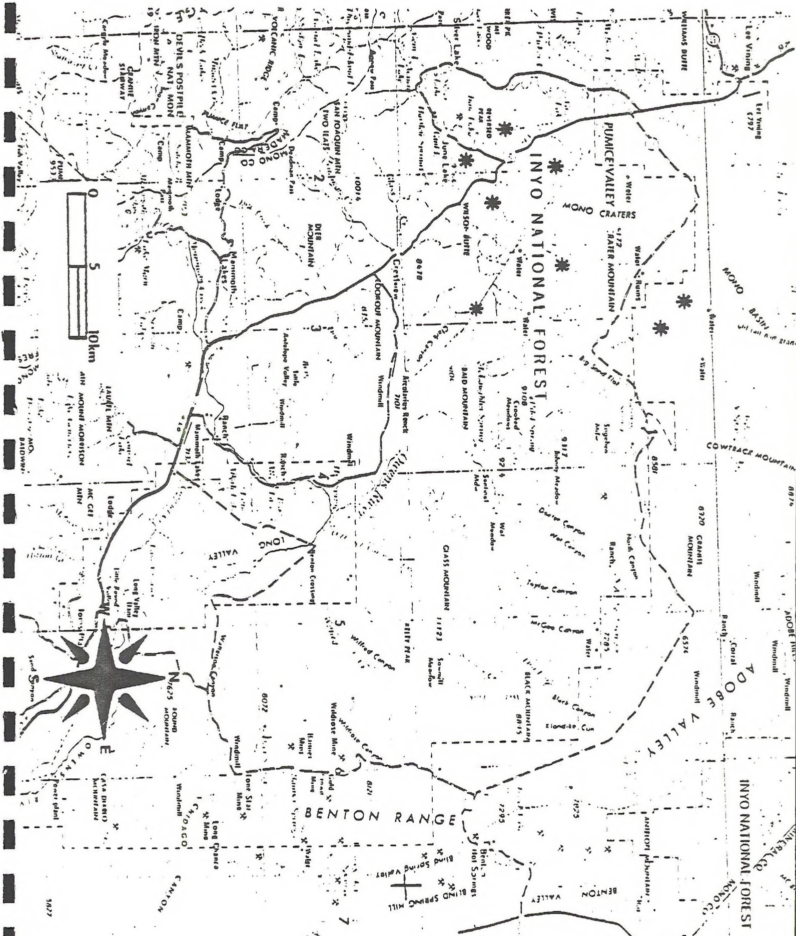
Appendix Figure 7b Recommended areas on the Casa Diablo winter range for establishment of rainwater collectors and guzzlers necessary for providing permanent water.



* Recommended Areas for Placement of Artificial Containers for Water on the Casa Diablo Winter Range

Blind Spring Valley
Blind Spring
Pumice Quarry
Prospects
Springs
Comanche Mine
Quarry
Tanner Ridge
Red Rock Canyon
1
2
3
4
5km
N
W

Appendix Figure [illegible] Recommended areas on the [illegible]
establishment of rainwater collectors and guzzlers necessary for providing permanent water.


INYO NATIONAL FOREST
INYO NATIONAL FOREST
Lee Vining
Lee Vining 6797
MONO BASIN
MONO CRATERS
PUMICE VALLEY
CRATER MOUNTAIN
ADOBE VALLEY
ADOBE HILLS
COWTRACK MOUNTAIN
GRANITE MOUNTAIN
8320
6574
8501
7285
North Canyon
Ranch
Corral
Water
Windmill
Ruins
Big Sand Flat
Sagehen Mdw
Johnny Meadow
Dexter Canyon
Hot Canyon
Taylor Canyon
McGee Canyon
Black Canyon
Klondike Can
BLACK MOUNTAIN 8815
Wet Meadow
Sentinel Mdw
Crooked Meadows
9108
9117
McLaughlin Spring
BALD MOUNTAIN
GLASS MOUNTAIN
11123
Sawmill Meadow
KELTY PEAK
Wilfred Canyon
Wildrose Canyon
Wildrose Mine
Gold Mine
Banner Mine
Lone Star Mine
Long Chance Mine
CHIDAGO CANYON
BENTON RANGE
Benton Hot Springs
Blind Spring Valley
BLIND SPRING HILL
BENTON VALLEY
ANTELOPE MOUNTAIN
7025
7295
8121
8072
MINERAL CO
MONO CO
WILLIAMS BUTTE
Silver Lake
June Lake
REVERSED PEAK
WILSON BUTTE
Crestview
8678
LOOKOUT MOUNTAIN
Arcularius Ranch 7101
Owens River
Glass Creek
Clark Canyon
Antelope Valley
Little Antelope Valley
10014
SAN JOAQUIN MTN
TWO TEATS
DEER MOUNTAIN
Deadman Pass
MADERA CO
MONO CO
VOLCANIC RIDGE
Agnew Pass
Camp
Lodge
Mammoth Lakes
MAMMOTH MTN
Mammoth Pass
PUMICE FLAT
DEVILS POSTPILE NAT. MON
IRON MTN
GRANITE STAIRWAY
Cargyle Meadow
PUMICE 9533
Fish Valley
LAUREL MTN
MOUNT MORRISON
MC GEE MTN
MT. BALDWIN
Mammoth Lakes 7133
Benton Crossing
LONG VALLEY
Watterson Canyon
ROUND MOUNTAIN
7625
CASA DIABLO MOUNTAIN
Long Valley Dam
Little Round Valley
Toms Place
Sand Canyon
OWENS
Power plant
5827
Ranch
Windmill
2
3
4
5
6
7
0
5
10km
N
E
W

APPENDIX F

SCENARIO FOR CUMULATIVE DEVELOPMENT

APPENDIX F: SCENARIO FOR CUMULATIVE DEVELOPMENT

1. EXISTING DEVELOPMENT

The land use discussion in Chapter 3, Section 3.3.7.1.2, lists a number of developments in the Project vicinity which contribute to environmental impacts. Among the existing facilities, MP I is the only one which pumps from a geothermal reservoir. The Town of Mammoth Lakes, not specifically listed as a nearby land use in Chapter 3, has about 5,000 permanent residents and up to 30,000 inhabitants on a busy winter weekend. It is located about three miles west of the Project site.

2. REASONABLE FORESEEABLE DEVELOPMENT

2.1 GEOTHERMAL DEVELOPMENT

Three geothermal projects in addition to PLES I have been proposed on private lands in the project vicinity. They are:

> Mammoth Pacific II & III: This project consists of two 12 MWe (net) geothermal projects under consideration for the Magma lease, immediately north of the PLES I site. Each plant would be similar to the Proposed Project.
>
> Mammoth Chance Unit I: This project, currently under litigation after having been approved on appeal by the Mono County Board of Supervisors, is a 10 MWe (net) geothermal project near Mammoth Creek opposite Hot Creek Hatchery. It would have an air cooled binary power plant.

A number of people have suggested that there is a real threat of massive development of geothermal projects in Long Valley. This cumulative scenario does not anticipate such development for the following reasons.

The existing and proposed geothermal developments described above are tied to special sales contracts known as Standard Offer Number 4 contracts authorized under the Federal Public Utilities Regulatory Policies Act of 1978 (PURPA) and developed through the California Public Utility Commission (CPUC). PURPA and the CPUC require electrical utilities to purchase electricity from small producers such as Pacific Energy, holding such contracts for the price which the utility avoids by not having to build additional generating capacity. The basic purpose is to provide economic incentive to developers of alternative energy sources, such as geothermal, in order to broaden and diversify both the nation's and California's energy base and lessen our dependence on foreign oil. Most of the geothermal facilities proposed and/or built in California since 1983 have been tied to Standard Offer Number 4 contracts. In April 1985, however, CPUC suspended the issuance of new Standard Offer Number 4 contracts and development without the benefit of such a contract is not economic under existing and foreseeable energy prices, it is not expected that any new geothermal power plants will be proposed in the Long Valley area within the foreseeable future.

Exploration activities on Federal leases will continue at a very low level in the Mono-Long Valley area for the foreseeable future. Most of the issued leases in the area are committed to two Federal Unit Agreements, the Long Valley East Unit covering 35,036 acres in Lease Block #1 and the Inyo Domes Unit covering 12,947 acres in Lease Block #2, immediately west of Lease Block #1. The PLES I project is located within the Long Valley East Unit areas.

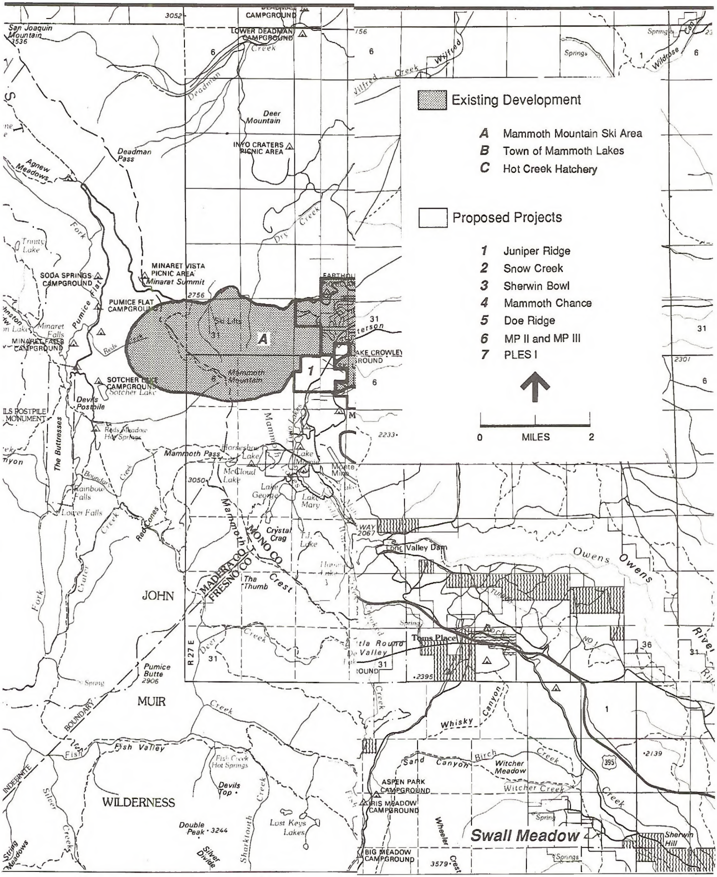
Unit agreements are legal contracts between lessees sharing a common exploration target and the BLM, for the orderly and timely exploration of the area. The unit operator is required to conduct exploration on a set schedule until a developable resource is discovered or until the operator determines that developable resources are not likely to be present. With the completion of the first PLES I production well, the exploration obligations for the Long Valley East Unit have been satisfied. With the exception of the Sandia Deep Hole, no further exploration wells, except of course those already proposed for the above listed projects, are expected to be drilled in the foreseeable future in the unit area.

The unit operator for the Inyo Domes Unit has drilled one exploration well (#44-16) to date. Another well will be required to be drilled by August 1, 1988 unless an extension of that obligation is granted by BLM. If the next well is unsuccessful, it is unlikely that the unit operator will drill another well. In that case, the unit agreement would terminate and the lease terms would control development. There is no requirement to drill under the lease terms. Even if a successful well were completed, it is unlikely that foreseeable economic conditions in the energy industry would make it possible to propose a viable power project. In aid of this, the industry is supporting Congressional efforts to provide for extensions of geothermal leases precisely because of the unfavorable energy economic climate and their inability to develop geothermal resources economically. Most likely, the operator would retain the status quo on the lease and not drill additional wells until economic condition change. Therefore, two additional wells, outside the Sandia Deep Hole, are expected in the Mono-Long Valley area in the foreseeable future. No additional power plant proposals are expected.

2.2 NON-GEOTHERMAL PROJECTS

Several proposals for recreational and commercial development near Mammoth Lakes have recently been announced. They include plans for expansion of existing, and development of new, downhill ski facilities, construction of several golf courses, hotels, restaurants, condominium developments, and shops. Not all the rumored projects will necessarily be built, and not all are appropriate for discussion in this document; so, in consultation with the Bureau of Land Management-Bishop Resource Area, Inyo National Forest, Mono County Planning Department, and the Mono County Office of Energy Management, the following list of relevant development projects was identified. Discussion of the cumulative impacts within each environmental resource section is limited to specifically identified projects from the following list which could contribute to a given cumulative impact with respect to the PLES I Project. The locations of the projects, listed below, are shown in Figure F-1. They are:

> Doe Ridge: Airport expansion, construction of a hotel, and a golf course have been proposed for the airport area and the ridge east of the airport. Water use at the project has been estimated at 760 cfs.
>
> Sherwin Bowl: Located immediately south of the Town of Mammoth Lakes, this downhill ski area development would include lifts and all appertenant facilities.



Existing Development
A Mammoth Mountain Ski Area
B Town of Mammoth Lakes
C Hot Creek Hatchery
Proposed Projects
1 Juniper Ridge
2 Snow Creek
3 Sherwin Bowl
4 Mammoth Chance
5 Doe Ridge
6 MP II and MP III
7 PLES I
0 MILES 2
San Joaquin Mountain 3536
Deadman Pass
Agnew Meadows
Deer Mountain
INYO CRATERS PICNIC AREA
LOWER DEADMAN CAMPGROUND
MINARET VISTA PICNIC AREA
Minarat Summit
SODA SPRINGS CAMPGROUND
PUMICE FLAT CAMPGROUND
MINARET FALLS CAMPGROUND
SOTCHER LAKE CAMPGROUND
Devils Postpile
Reds Meadow Hot Springs
Mammoth Pass
Ski Lifts
Mammoth Mountain
The Buttresses
Rainbow Falls
Lower Falls
Red Cones
Horseshoe Lake
McCloud Lake
Lake George
Lake Mamie
Lake Mary
Crystal Crag
T.J. Lake
MADERA CO
FRESNO CO
MONO CO
Mammoth Crest
The Thumb
Long Valley Dam
Owens River
Toms Place
JOHN MUIR WILDERNESS
Pumice Butte 2906
BOUNDARY
INDEFINITE
Fish Valley
Fish Creek Hot Springs
Devils Top
Double Peak 3244
Silver Divide
Lost Keys Lakes
String Meadows
Whisky Canyon
Sand Canyon
Witcher Meadow
Witcher Creek
Birch Creek
ASPEN PARK CAMPGROUND
IRIS MEADOW CAMPGROUND
BIG MEADOW CAMPGROUND
Wheeler Crest 3579
Swall Meadow
Sherwin Hill
395
R 27 E

FIGURE F-1
Regional Map for Cumulative Analyses

SOURCE: ESA, Inc., 1988

Snow Creek: This project would be located in Mammoth Meadow, between Sherwin Bowl and the developed part of the Town of Mammoth Lakes. It would include a golf course, hotels, condominiums, restaurants, and a convention facility.

Juniper Ridge: This project, located between Mammoth Mountain and the Town of Mammoth Lakes, would expand the facilities associated with Mammoth Mountain skiing. It would include a hotel, condominiums, a ski lodge, and commercial space.

Town of Mammoth Lakes Projects: Golf Course; Mammoth Water District Water Project; and Economic Development Corporation plans for Industrial Center at Old Mammoth School.

3. CUMULATIVE ISSUES DISMISSED

The following projects were evaluated in the cumulative impact assessment in this document; however, for the reason identified for each project, it was determined to be inappropriate to analyze the potential cumulative hydrologic impacts from these projects with respect to the proposed PLES I project.

3.1 UNOCAL AND SANTA FE POWER PLAN PROJECTS

Neither Unocal nor Santa Fe has announced any plans to construct a power plant using geothermal fluid in the near future and exploration efforts have ceased. No power contracts are likely to be available within the next few years, and startup would not occur until at least five years after that. Therefore, it would be unreasonable, particularly without reservoir data in those lease areas, to assume project size production, temperatures depths, flowrates, and time scale for the purpose of estimating cumulative impacts.

3.2 TOWN OF MAMMOTH LAKES GEOTHERMAL DISTRICT HEATING PROJECT

Though the town appears likely to receive appropriate funding for such a project and has acquired significant exploration data, deeper drilling would be required to reach fluids with appropriate temperatures. For such a project, both temperature and available fluid are related and required design parameters. The scale (i.e., project size and flow required) of an initial test phase project is dependent upon a number of other factors such as production and injection well locations, realistic demand and growth potential, and users available within a suitable radius of the projection wells. Many of these would be pure guesswork at this time and without sound bases to use in calculating hydrologic impacts. It is possible that a pilot project startup could occur within five years, but the flowrate of geothermal fluid would be orders of magnitude less than required for a 10 MW power plant.

3.3 TOWN OF MAMMOTH LAKES WATER SUPPLY WELLS AND GOLF COURSE

These projects are not included in the cumulative hydrologic analysis for three reasons: 1) Neither project has specific criteria for actual use; and 2) the PLES I project would not draw a significant amount of shallow fresh water relative to these projects; and 3) The PLES I project is not believed to produce from the same aquifers. It is not appropriate to attempt an analysis without some evidence of hydraulic communication between them. The shallow groundwater use at Casa Diablo is specifically for fire protection and landscaping only. Much of the irrigation water will likely return to the same groundwater source. See Chapter 2 on proposed use and Chapter 4 on effects.

There is some speculation that the town water wells in question generate the freshwater aquifer supplying Hot Creek Hatchery springs. If both freshwater and thermal components were influenced by one or more projects some combined effect on the springs is possible. However, such theories are not supported by data since hydraulic communication between any of the three features is not established. Further, attempts to quantify the potential for cumulative impacts would be impossible in the absence of such data.

APPENDIX G

GRO ORDER NUMBER 4:

GENERAL ENVIRONMENTAL PROTECTION REQUIREMENTS

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CONSERVATION DIVISION

GEOTHERMAL RESOURCES OPERATIONAL ORDER NO. 4

Effective August 1, 1975

GENERAL ENVIRONMENTAL PROTECTION REQUIREMENTS

This Order is established pursuant to the authority prescribed in 30 CFR 270.11 and in accordance with 30 CFR 270.2, 270.34(k), 270.37, 270.41, 270.42, 270.43, 270.44, and 270.76. Lessees shall comply with the provisions of this Order. All variances from the requirements specified in this Order shall be subject to approval pursuant to 30 CFR 270.48. References in this Order to approvals, determinations, or requirements are to those given or made by the Area Geothermal Supervisor (Supervisor) or his delegated representative.

All data submitted under this Order shall be available for inspection in accordance with the Freedom of Information Act of 1966 (P.L. 89-487), as amended in 1974 (P.L. 93-502), except information such as geological, geophysical, reservoir, trade secrets, and financial data and interpretations of such data, maps, and related files for which a lessee requests proprietary status; provided that such status is determined by the Supervisor to be warranted and is approved by appropriate officials of the Department of the Interior.

Protection of the environment includes the lessee's responsibility to: conduct exploration and development operations in a manner that provides maximum protection of the environment; rehabilitate disturbed lands; take all necessary precautions to protect the public health and safety; and conduct operations in accordance with the spirit and objectives of all applicable Federal environmental legislation and supporting executive orders.

Adverse environmental impacts from geothermal-related activity shall be prevented or mitigated through enforcement of applicable Federal, State, and local standards, and the application of existing technology. Inability to meet these environmental standards or continued violation of environmental standards due to operations of the lessee, after notification, may be construed as grounds for the Supervisor to order a suspension of operations.

The lessee shall be responsible for the monitoring of readily identifiable localized environmental impacts associated with specific activities that are under the control of the lessee. Monitoring of environmental impacts may be conducted by the use of aerial surveys, inspections, periodic samplings, continuous recordings, or by such other means or methods as required by the Supervisor. Due to the differing natural environmental conditions among geothermal areas, the extent and frequency of such monitoring activities will be determined by the Supervisor on an individual basis. In the event the Supervisor determines that the degree and adequacy of existing environmental protection regulations in certain areas are insufficient, the Supervisor may establish additional and more stringent requirements by the issuance of field orders or by modifying existing orders.

Lessees shall provide for acquisition of environmental baseline data as required in accordance with 30 CFR 270.34(k) for a period of one year prior to submission of a plan for production. Techniques and standards to be used by the lessee for meeting these requirements shall receive prior approval by the Supervisor.

1. Aesthetics. The lessee shall reduce visual impact, where feasible, by the careful selection of sites for operations and facilities on leased lands. The design and construction of facilities shall be conducted in a manner such that the facilities will blend into the natural environmental setting of the area by the appropriate use of landscaping, vegetation, compatible color schemes, and minimum profiles. Native plants or other compatible vegetation shall be used, where possible, for landscaping and revegetation.

2. Land Use and Reclamation. Operating plans shall be designed so that operations will result in the least disturbance of land, water, and vegetation. Existing roads shall be used where suitable. Entry upon certain environmentally fragile land areas, as designated by the surface management agency, may be either seasonally restricted or restricted to special vehicles or transportation methods which will minimize disturbance to the surface or other resources as specified by the Supervisor and surface management agency.

Operating plans shall provide for the reclamation and revegetation of all disturbed lands in a manner approved by the Supervisor and the appropriate surface management agency. Land reclamation may include preparation and seeding with prescribed wildlife food and plant cover or improved and acceptable substitutes thereof which will equal or enhance the food values for indigenous wildlife species and domesticated animals. Temporary fencing for such reclaimed areas may be required to facilitate restoration thereof.

The lessee shall at all times maintain the leased lands in a safe and orderly condition and shall perform the operations in a workmanlike manner. The lessee shall remove or store all supplies, equipment, and scrap in a timely and orderly fashion.

Operations under a geothermal lease shall not unreasonably interfere with or endanger operations under any other lease, license, claim, permit, or other authorized use on the same lands.

3. Public Access. The public shall have free and unrestricted access to geothermal leased lands, excepting however, where restrictions are necessary to protect public health and safety or where such public access would unduly interfere with the lessee's operations or the security thereof. The lessee shall provide warning signs, fencing, flagmen, barricades, or other safety measures deemed necessary by the Supervisor to protect the public, wildlife, and livestock from hazardous geothermal or related activities.

4. Recreation. Recreational values shall be adequately protected through planning and designing of site development to minimize the aesthetic degradation of the particular recreation area. The lessee shall generally be restricted from surface locations for drilling and other lease operations within 61 metres (200 feet) of established recreation sites and access routes thereto. However, the lessee may relocate a recreational site and/or access routes thereto when approved by the Supervisor with the concurrence of the land management agency.

5. Slope Stability and Erosion Control. Operations shall be conducted in such a manner so as to minimize erosion and disturbance to natural drainage. The lessee shall provide adequate erosion and drainage control to prevent sediments from disturbed sites from entering water courses for soil and natural resource conservation protection.

Mitigating measures to lessen environmental damage may include reseeding of disturbed soils, chemical stabilization, and dust and erosion control on well sites, roads, and construction areas.

All operating plans shall give proper consideration to the potential hazards of slope instability. Where potentially unstable ground conditions exist, design of proposed roads, drill sites, and surface facilities shall be approved by and constructed under the supervision of a qualified engineer or engineering geologist satisfactory to the Supervisor.

6. Biota. The lessee shall conduct all operations in such a manner as to afford reasonable protection of fish, wildlife, and natural habitat. The lessee shall take such measures as are necessary for the conservation of endangered and threatened species of flora and fauna as set forth in applicable executive orders, regulations, and State or Federal legislation such as the Endangered Species Act of 1973 and the Fish and Wildlife Coordination Act. When such species would be adversely affected by the lessee's operations on the leased lands, the lessee shall implement those measures necessary to minimize or eliminate such adverse effects and to protect the flora and fauna as specified by the Supervisor in accordance with recommendations by appropriate Federal and State agencies. Such measures may be in addition to provisions set forth in the lease or accompanying stipulations.

The Supervisor may receive information from recognized experts that a delicate balance of flora and/or fauna exists in the area of operations or proposed operations. Upon receiving such notice, the Supervisor will request timely advice and assistance from appropriate Federal and State agencies regarding: (1) an assessment of the status of flora and fauna in the area which may be adversely affected by operations, and (2) advice as to reasonable mitigating measures appropriate to minimizing or preventing adverse trends in populations, growth, vegetative recovery, or repopulations in potentially affected flora and/or fauna. Based on timely receipt of advice from appropriate agencies, the Supervisor will direct the lessee to take appropriate measures to minimize significant adverse trends in flora and fauna. Such measures may include, but not be limited to, revegetation with grasses, shrubs, or other vegetation of high forage values desirable for habitat, replacement of fauna where lost, replacement of water supply, or sources where destroyed.

Where the lessee's operations have destroyed significant flora and/or fauna or their natural habitat and replacement by natural processes will not take place in a normal growth cycle, the lessee shall take reasonable measures to replace those species or their habitat with the same or other acceptable species or habitat as directed by the Supervisor. The Supervisor's requirements shall be based on recommendations and advice received from appropriate Federal and State agencies.

7. Cultural Resources Preservation. The lessee shall exercise due diligence in the conduct of his operations to protect and preserve significant archaeological, historical, cultural, paleontological, and unique geologic sites. The lessee shall not disturb any known cemetery or burial ground of any group or culture.

Previously unknown sites uncovered by the lessee shall be immediately reported to the Supervisor, and operations on the particular site shall cease until said site can be assessed for its archaeological value and preservation. Necessary controls and remedial actions for the protection and preservation of cultural resources shall be issued on an individual site basis by the Supervisor as warranted.

The preservation, restoration, maintenance, and nomination of all resources for purposes of the National Register of Historic Places shall be in accordance with the provisions of Executive Order 11593 (36 FR 8921) entitled, "Protection and Enhancement of the Cultural Environment," or any amendments thereto.

8. Subsidence and Seismicity. Surveying of the land surface prior to and during geothermal resources production will be required for determining any changes in elevation of the leased lands. Lessees shall make such resurveys as required by the Supervisor to ascertain if subsidence is occurring. Production data, pressures, reinjection rates, and volumes shall be accurately recorded and filed monthly with the Supervisor as provided in 30 CFR 270.37. In the event subsidence activity results from the production of geothermal resources, as determined by surveys by the lessee or a governmental body, the lessee shall take such mitigating actions as are required by the lease terms and by the Supervisor.

If subsidence is determined by the Supervisor to present a significant hazard to operations or adjoining land use, then the Supervisor may require remedial action including, but not limited to, reduced production rates, increased injection of waste or other fluids, or a suspension of production.

A. Surveys. All required surveys shall be second order or better and shall be conducted under the direct supervision of a registered civil engineer or licensed land surveyor using equipment acceptable by the National Ocean Survey for second order surveys. All such work shall be coordinated with the county surveyor of the county in which the surveys and bench marks are to be established. Level lines and networks shall be tied to available regional networks.

Adjusted survey data shall be filed with the Supervisor within 60 days after leveling is completed. Any lessee having a commercially productive geothermal well or wells shall participate in cooperative County/State subsidence detection programs. All survey data filed with the Supervisor shall be available to the public.

B. Bench Marks. One or more wellsite bench marks shall be required at each completed well prior to prolonged production and said bench marks shall be located in a manner such that there is a minimal probability of destruction or damage to said bench marks. Wellsite bench marks shall be tied to existing regional networks. Additional bench marks between the wellsites and the regional network shall be at 0.8-km (one-half mile) intervals or as otherwise specified by the Supervisor. These bench marks shall be resurveyed during well production operations on a periodic basis as determined by the Supervisor.

Acceptable bench marks include, but are not limited to, a brass rod driven to refusal or 9 metres (about 30 feet) and fitted with an acceptable brass plate or a permanent structure with an installed acceptable brass plate.

C. Reservoir Data. Initial reservoir pressure and temperature shall be reported to the Supervisor in duplicate on Well Completion or Recompletion Report (Form 9-330C) for all completed wells within 30 days after the completion of measurements or tests conducted for the purpose of obtaining such data. Initial production test data including steamwater ratio, surface pressure and temperature, quality, and quantity of well effluent shall also be filed with the Supervisor on Form 9-330C within 30 days after a well is completed.

D. Seismicity. The installation of seismographs or other like instruments in producing geothermal areas for the purpose of detecting potential seismic activity may be initiated from time to time by appropriate public agencies. Lessees shall cooperate with the appropriate public agencies in this regard. The lessee and the appropriate public agency should take care not to unreasonably interfere with or endanger each other's respective operations. The Supervisor shall coordinate such detection programs between the appropriate public agency conducting the program and the lessee.

Where induced seismicity caused by the production of geothermal fluids is determined to exist by the Supervisor, then the Supervisor may require the lessee to install such monitoring devices as necessary to adequately quantify the effects thereof. If induced seismicity is determined to represent a significant hazard, the Supervisor may require remedial actions including, but not limited to, reduced production rates, increased injection of waste or other fluids, or suspension of production.

9. Pollution, Waste Disposal, and Fire Prevention. The lessee shall comply with all applicable Federal and State standards with respect to the control of all forms of air, land, water, and noise pollution, including the control of erosion and the disposal of liquid, solid, and gaseous wastes. The Supervisor may, at his discretion, establish additional and more stringent standards. Plans for disposal of well effluents must be approved by the Supervisor before any implementation action is undertaken. Immediate corrective action shall be taken in all cases where pollution has occurred.

The lessee shall timely remove or dispose of all waste including human waste, trash, refuse, and extraction and processing waste generated in connection with the lessee's operations in a manner acceptable to the Supervisor.

The lessee shall provide safeguards to minimize potential accidental fires and shall instruct field personnel in fire-prevention methods. The lessee shall maintain fire-fighting equipment in working order at strategic locations on the leased lands.

A. Pollution Prevention. In the conduct of all geothermal operations, the lessee shall not contaminate any natural waters and shall minimize adverse effects on the environment.

(1) Liquid Disposal. Liquid well effluent or the liquid residue thereof containing substances, including heat, which may be harmful or injurious and cannot otherwise be disposed of in conformance with Federal, State, and regional standards, shall be injected into the geothermal resources zone or such other formation as is approved by the Supervisor.

Toxic drilling fluids shall be disposed of in a manner approved by the Supervisor and in conformance with applicable Federal, State, and regional standards.

(2) Solid Waste Disposal. Drill cuttings, sand, precipitates, and other solids shall be disposed of as directed by the Supervisor either on location or at other approved disposal sites. Containers for mud additives for chemicals and other solid waste materials shall be disposed of in a manner and place approved by the Supervisor.

(3) Air Quality. Noncondensible gases such as carbon dioxide, ammonia, and hydrogen sulfide may be vented or ejected into the atmosphere, provided, however, that the volume and the measured concentration of such vented gas or gases shall not exceed applicable Federal, State, or regional air pollution standards. Copies of each permit issued by the appropriate air pollution control agency and the reports required thereunder shall be submitted to the Supervisor.

(4) Pits and Sumps. Pits and sumps shall be lined with impervious material and purged of environmentally harmful chemicals and precipitates before backfilling. In no event shall the contents of a pit or sump be allowed to contaminate streams, lakes, and ground waters. Pits and sumps shall be constructed in a manner and in such locations so as to minimize damage to the natural environment and aesthetic values of the lease or adjacent property. When no longer used or useful, pits and sumps shall be backfilled and the premises restored to as near a natural state as reasonably possible. Temporary fencing of unattended pits and sumps to protect wildlife, livestock, and the public may be required by the Supervisor and the surface management agency.

(5) Production Facilities Maintenance. Production facilities shall be operated and maintained at all times in a manner necessary to prevent pollution. The lessee's field personnel shall be instructed in the proper maintenance and operations of production facilities for the prevention of pollution.

B. Inspection and Reports. Lessees shall comply with the following pollution inspection and reporting requirements.

(1) Pollution Inspections. Drilling and production facilities shall be inspected daily by the lessee. Appropriate preventative maintenance shall be performed as necessary to prevent failures and malfunctions which could lead to pollution. Wells and areas not under production shall be inspected by the lessee at intervals prescribed by the Supervisor. Necessary repairs or maintenance shall be made as required.

(2) Pollution Reports. All pollution incidents shall be reported orally within 18 hours to the appropriate Geothermal District Supervisor and shall be followed within 30 days thereof by a written report stating the cause and corrective action taken.

C. Injection. The use of any subsurface formation, including the geothermal resources zone for the disposal of well effluent, the residue thereof, or the injection of fluids for other purposes such as subsidence prevention shall not be permitted until the lessee has submitted a plan of injection covering the proposed injection project and has subsequently received the Supervisor's written approval thereof.

(1) Plan of Injection. The plan of injection shall include the quantity, quality, and source of the proposed injection fluid; the means and method by which the fluid is to be injected; a structure map contoured on the intended injection zone; and cross-sections showing producing well locations and the proposed injection well location(s).

(2) Injection Report. The lessee shall file in duplicate with the Supervisor a Monthly Water Injection Report in a form approved by the Supervisor. The subject report shall be filed on or before the last day of the month following the month in which the injection took place.

(3) Inspection. Injection wells and facilities shall be inspected by the lessee at intervals as prescribed by the Supervisor to ascertain that all injected fluids are confined to the approved injection zone. A spinner survey, a radioactive tracer survey, and a cement bond log may be required on each injection well within 30 days after injection begins. The lessee shall furnish to the Supervisor two legible exact copies of any and all such surveys and logs. In the event of a casing failure, inadequate annular cement, or other mechanical failure, the lessee shall without unreasonable delay repair, suspend, or abandon the well. Where failure occurs in a zone which may damage surface or fresh water aquifers, injection shall immediately cease.

(4) New Wells. The drilling of new injection wells in accordance with an approved plan of injection shall be in conformance with the provisions of GRO Order No. 2. An Application for Permit to Drill, Form 9-331C, shall be filed in triplicate and approved for each injection well.

(5) Conversions. The conversion of an existing well to an injection well in accordance with or modification of an approved plan of injection shall be in conformance with the requirements of GRO Order No. 2. The lessee shall demonstrate to the satisfaction of the Supervisor by appropriate testing and logging that the well is mechanically sound and suitable for injection purposes. A Sundry Notice, Form 9-331, shall be filed in triplicate and approved for each conversion.

10. Water Quality. The primary responsibility for water quality and pollution control has been delegated to the States where such States have standards approved by the Environmental

Protection Agency. Such State standards must meet basic Federal requirements prohibiting the deterioration of waters whose existing quality is higher than established water quality standards. The lessee shall comply with the State water quality control organization's standards in such States as have federally-approved standards. The Supervisor, at his discretion, may establish additional and more stringent standards.

The lessee shall file, in duplicate, a detailed water analysis report for all completed geothermal wells within 30 days after completion and annually thereafter or as otherwise specified by the Supervisor. Unless otherwise prescribed by the Supervisor, such analyses shall include a determination of arsenic, boron, radioactive content, and radioactivity of the produced fluids. In the event that a health hazard exists, the Supervisor shall require appropriate health and safety precautions, periodic monitoring, or the suspension of production.

11. Noise Abatement. The lessee shall minimize noise during exploration, development, and production activities. The method and degree of noise abatement shall be as approved by the Supervisor.

The lessee shall conduct noise level measurements during exploration, development, and production operations to determine the potential objectionability to nearby residents as well as the potential health and safety danger due to noise emissions.

Noise level measurements and accompanying data shall be filed with the Supervisor. Such data shall provide the basis for operational and noise control decisions by the Supervisor and shall be based on an assessment of the noise relative to Federal or State criteria including adjustments for the area involved, meteorological conditions, and the time of day of the noise occurence.

The lessee shall comply with Federal occupational noise exposure levels applicable to geothermal activity under the Occupational Safety and Health Act of 1970 as set forth in 29 CFR 1910.95, which are incorporated herein by reference, or with State standards for protection of personnel where such State standards are more restrictive than Federal standards.

A. Measurement Condition. Outdoor noise measurements shall be made at least 3 metres (10 feet) from structures, facilities, or other sound reflecting sources and approximately 1 metre (3 feet) above ground level. Extreme weather conditions, electrical interference, and unusual background noise levels shall be avoided or given due consideration when measuring sound levels.

B. Measurements. The lessee shall monitor and measure noise levels using an octave band noise analyzer with an A-weighted frequency response or a standard sound level meter that conforms to the requirements set forth in USA Standard Specifications for General Purpose Sound Level Meters USASI S1.4-1961 or the latest approved revision thereof. Bandpass filters shall conform to the requirements of USASI S1.11-1966. The lessee shall measure noise level frequency distribution as required by the Supervisor. Sound levels shall be measured in conformance with the USA Standard-Method for the Physical Measurement of Sound USASI S1.2-1962.

C. Criteria. In the absence of more restrictive criteria as may be established in this paragraph, the lessee shall not exceed a noise level of 65 dB(A) for all geothermal-related activity including but not limited to, exploration, development, or production operations as measured at the lease boundary line or 0.8 km (one-half mile) from the source, whichever is greater, using the A-weighted network of a standard Sound Level Meter. However, the permissible noise level of 65 dB(A) may be exceeded under emergency conditions or with the Supervisor's approval if written permission is first obtained by the lessee from all residents within 0.8 km (one-half mile).

D. Assessment. The lessee shall be responsible for taking such noise level measurements as are deemed necessary by the Supervisor. The background noise level shall serve as the criterion for the rating and assessment, by the Supervisor, of the objectionableness of noise emission from a particular source. The background or ambient noise is defined hereby as the minimum sound level at the relevant place and time in the absence of the source noise and shall include consideration for the type of land use, the season, atmospheric conditions, and the time of day.

E. Attenuation. To attenuate objectionable noise, the lessee shall utilize properly designed muffling devices as required by the Supervisor.

F. Relationships. Reference levels and relationships for noise measurements shall be as follows:

(1) Reference sound pressure for airborne sounds shall be 20 MN/m (20 micronewtons per square metre).

(2) Reference power shall be 10-12 watts.

(3) Sound levels shall be measured using a standard Sound Level Meter with an "A" frequency response characteristic (weighting network).

(4) Sound level meter controls shall be set for as uniform a frequency response as possible when measuring sound pressure levels.

(5) Octave band noise levels shall be reported in equivalent A-weighted levels.

G. Record of Sound Measurements. The Supervisor may require sound level measurements during drilling, testing, and producing operations. Such measurements shall be filed in duplicate with the Supervisor and shall include the following data:

(1) Date, time, and location.

(2) Name of observer.

(3) Description of primary noise source emitter under test.

(4) Kind of operation and operating conditions.

(5) Description of secondary noise sources including location, type, and kind of operation.

(6) Type and serial numbers on all microphones, sound level meters, and octave band analyzers used. Length and type of microphone cables.

(7) Position of observer.

(8) Direction of arrival of sound with respect to microphone orientation.

(9) Approximate temperature of microphone.

(10) Results of maintenance and calibration tests.

(11) Weighting network and meter speed used.

(12) Measured overall response and band levels at each microphone position and extent of meter fluctuation.

(13) Background overall response and band levels at each microphone position with primary noise source not operating.

(14) Cable and microphone corrections.

(15) Any other pertinent data such as personnel

exposed directly and indirectly, time pattern of the exposure, atmospheric conditions, attempts at noise control, and personnel protection.

Reid T. Stone
Area Geothermal Supervisor

APPROVED:

Russell G. Wayland

Russell G. Wayland
Chief, Conservation Division

APPENDIX H

EVALUATION OF S. S. PAPADOPULOS HYDROLOGIC REPORT

cc [illegible]
D. Caldwell
D. Covey
D. Campbell
ML 3008 3.3

DRAFT

MINUTES

LONG VALLEY HYDROLOGIC ADVISORY COMMITTEE (LVHAC)
REGULAR MEETING
JANUARY 12, 1989

The January 12th meeting of the LVHAC was called to order by the Director of Energy Management, Mono County, Dan Lyster, at approximately 1:00 p.m. at the Mammoth Lakes Fire Department conference room. The list of individuals in attendance and their respective agency/company affiliations are as follows:

Ted Van de Sande	California Fish & Game
Christopher Farrar	US Geological Survey
Curtis Milliron	California Fish & Game
Robert Habel	California Div. of Oil & Gas
Dick Thomas	California Div. of Oil & Gas
Brent Lamkin	BLM-Bishop
Cheryl Closson	California Energy Commission
Dan Lyster	Mono County
Mike Walker	Pacific Energy/Mammoth Pacific
Jack Barnett	Bonneville Pacific
Mark Ziegenbein	BLM-Bishop
Don Campbell	Mesquite Group
Thom Heller	USFS-Mammoth
John Eastman	Town of Mammoth Lakes
Dan Paranick	Mono County
Dick Dahlgren	California Trout
Michael Jarvis	Mammoth Times
Gudmundur Bodvarrson	Private Consultant for Mono Co.
Ellen Hardebeck	Great Basin APCD
Andrea Lawrence	Mono County
Rob Willis	Miller & Wood Ranch Co.
Timothy Durbin	Papadopulos and Associates
Claudia Stone	Papadopulos and Associates

I. DISCUSSION OF MINUTES OF NOVEMBER 9, 1988, REGULAR MEETING

The minutes as proposed and circulated were discussed. The date of the meeting was corrected to show November 9, 1988, and the name of Ted Van de Sande, from the California Department of Fish and Game, was added to the list of attendees. With those minor corrections, the minutes were accepted and approved by the committee.

II. DISCUSSION AND POSSIBLE ACTION ON LVHAC SUBMITTING A COMMENT LETTER TO MONO COUNTY AND BLM REGARDING THE EFFECTIVENESS OF HYDROLOGIC MONITORING IN LONG VALLEY

Dan Lyster explained to the committee that following the November 9, 1988, meeting of the committee, efforts were made to prepare and forward a letter to the Mono County Board of Supervisors and the Bureau of Land Management (BLM) concerning the effectiveness of the hydrologic monitoring effort. California Department of Fish and Game representatives objected to the sending of the proposed letter because they were not in attendance at the November 9 meeting and did not have an opportunity to discuss this proposed expression of the committee's feelings with respect to this subject matter. Further, their objection stated that the proposal to forward such a letter was not placed before the committee in a proper way by advanced notice and identification as an agenda item.

Dan explained that he then felt it best to delay action on this agenda item until the next meeting of the HAC. Hence, it is scheduled for the HAC to discuss the proposed letter today. It was also pointed out by Dan that this agenda item could perhaps best be discussed after the committee had heard the presentations in connection with agenda item III. Therefore, at this point in time, the committee turned its attention to agenda item III.

III. PRESENTATION AND DISCUSSION OF METHODOLOGY USED BY MR. TIM DURBIN (PAPADOPULOS AND ASSOCIATES) IN PREPARING THE "SECOND" PAPADOPULOS REPORT

Dan asked California Fish and Game and Mr. Curtis Milliron to take the lead with respect to this agenda item. Curtis indicated that the presentation would be made by Tim Durbin and Claudia Stone. Claudia explained that she had taken all of the information which was available concerning geology and hydrology in the area and converted it into a conceptual model. She stated that Durbin then turned it into a math model. Claudia explained that she tried to put all she could find and all that was know and written about into a conceptual model.

The geologic information available is incomplete, particularly concerning stratigraphy and structures. Geologic units of interest are the Bishop Tuff and the Early Rhyolites. The elevation of the top of the Bishop Tuff and the thickness of the Bishop Tuff vary. The top of the Bishop Tuff is perhaps weathered and permeable. The center of the Bishop Tuff is dense and permeability must rely upon secondary permeability. This secondary permeability could be closed off with clays or minerals which might have been deposited in the opening of the fractures.

All of the above variabilities can also apply to the Early Rhyolites. There is a question of what affect these changes have on the hydrologic system. Water moves from its meteoric source, perhaps through ring fractures, through the system and then must come out of the ground-water system. The questions are how and where.

1. Evaporation

2. Ground-water discharge to the surface

3. Ground water leaving the area

Claudia stated that the USGS says that none of the water goes out of the Owens Valley as ground-water discharge, so if you subtract evaporation and transpiration, the remainder must be discharged to the surface water. The USGS contour maps do not deflect at faults, so faults are not effective in controlling ground-water flow. The map primarily represents the cold water system. The question is, "Is this also true of the deeper geothermal system?"

Claudia then asked the question, "What do bore holes tell us about the thermal system?"

1. To date, an upflow zone has not been identified.

2. Temperature profiles at M-1 (not Bonneville Pacific's M-1) show two thermal systems. It's in the younger rhyolite and the rubbly top of the Bishop. At M-1, the higher zone is hotter than the deeper zone. Bore holes across the dome vary some with respect to gradient--some without a gradient, some are very hot, some are not so hot.

3. Chemical geothermometers indicate 220°C+ at well #3416 near Inyo Crater and at Shady Rest. Some wells have been drilled and find a hip in the temperature gradient, but no shoulder. Other wells show both hips and shoulders on a plot of temperature gradients. Question: Is there greater than 220°C in an upwelling zone, and can we locate it?

Geology has been published by the USGS, Bailey and others. Some experts have mapped but not released their data. Much geophysics has been done. It has been a place to try new techniques, because it is a known geothermal area. Norquest, in 1987, did magneto-telluric work. Resistivity can vary with heat or clay. He found two lows that connected together form a horseshoe-shaped anomaly that swings around the dome. He defined the west side of the horseshoe as being an anomaly because of heat, and the east side of the horseshoe as being an anomaly because of clay.

Geochemistry shows the same source of water everywhere. Isotopes show that the fluids have been flowing through basement rock. So there are questions:

1. What controls the flow in the thermal aquifers?

2. Is there hydrologic continuity between the upper and lower thermal systems?

In the thermal zone, Claudia stated that there are indications that the lower zone is hydrologically continuous under the dome. With respect to the upper zone, the Bishop Tuff, it is not continuous in the western mote to the south mote, although there is upwelling in both areas on faults which occur, but this movement of thermal fluids may not be large and may not be important.

So Claudia indicated that her model has a major upwelling of fluids in the west mote near the resurgent dome, and then her model moves 220°C water from the west around to the south mote. She justifies this based in part on the magneto telluric work and data from the Shady Rest well.

With respect to the shallow thermal zone, water comes around the corner, so to speak, and a component discharges in springs, but much of it rises out into the Crowley Basin. Bishop Tuff water comes around the corner, discharges along a little hot creek, then moves east and is diluted and cooled before discharging. The upflow from the Bishop Tuff is basically in the Shady Rest area.

Tim Durbin then presented the mathematic model that he developed from Claudia's conceptual model. He decided to use a uniform lateral flow. Durbin went on to explain he assumed two horizontal layers, the horseshoe-shaped aquifer and an aquifer with a total thickness of 700 meters. He provided for the two-layered aquifer water flow and heat to move by flow and conductivity. He indicated there was not enough temperature data to describe a three-dimensional model system, so he had to make several assumptions. His study, thus far, shows that the temperature affects are much less than the hydrologic affects.

A discussion followed where there seemed to be general consensus that temperature is really not a problem with respect to the developers. The Papadopulos study, however, did find water level declines based on their many assumptions at the springs, because when analyzing the Pacific Energy efforts, the injection was into the lower aquifer. They show in their model no vertical movement from those injected fluids into the shallower aquifer, hence it was a depletion in the model to the fish hatchery and other springs.

1. Monitoring is to learn of changes. He believes that monitoring can and should be done to determine if there are changes and what is the nature of those changes.

2. Monitoring is to determine if adverse changes are occurring and if you can then respond and reverse those changes.

There was a long discussion and exchange of ideas between committee members and Mr. Durbin, particularly focusing on statements in the Papadopulos report and statements made by Mr. Durbin in the past concerning the effectiveness or the lack of effectiveness of monitoring. Durbin finally stated that he thinks that monitoring is very important and that monitoring can measure changes, and with that monitoring, the system will be better understood. Without the monitoring tool, we will never be able to better understand the system.

The committee concluded in their discussions that Tim's statement in the Papadopulos report does not accurately indicate his current position. Tim responded by indicating that what he was trying to say, and did not elaborate in the Papadopulos report, was that monitoring in and of itself would not reverse adverse impacts. He believed that modeling should be occurring now so that the system could be better understood and so that changes observed by the monitoring program could be inserted into a model.

He was further concerned that monitoring in and of itself did not assure that responsible government agencies would respond to the changes observed and require that actions be taken to reverse those changes. If the regulatory body did not act in a timely manner but perhaps procrastinated for many years, perhaps tens of years, then the impact of the development which was monitored could be widespread in the system, and potentially could not be reversed.

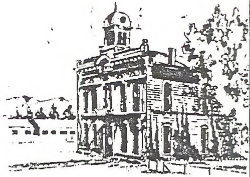
The committee then determined that it would send a letter to the Board of Supervisors and BLM officials. Dan askad that comments be back to him as to what should be contained in the letter by January 27. He indicated he would then send out the proposed letter to the committee for approval.

In conclusion, Dan stated that he is trying to schedule the next meeting of the LVHAC for some time in March. He will be in contact with committee members as to the time of that meeting.

Respectfully submitted,

Jack Barnatt

COUNTY of MONO
ENERGY MANAGEMENT DEPARTMENT
HCR 79, Box 221
Mammoth Lakes, CA 93546
(619) 934-6704, Ext. 403



DANIEL L. LYSTER
Director

April 3, 1989

Mr. Mike Ferguson
Bureau of Land Management
873 N. Main Street
Suite 201 Room 1310
Bishop, CA 93514

Dear Mr. Ferguson,

Recently the California Department of Fish and Game (DFG) and their hydrology consultant, S.S. Papadopulos & Associates, Inc. (specifically, Mr. Timothy J. Durbin, Western Regional Manager), have alleged that the monitoring program established by the Long Valley Hydrologic Advisory Committee (LVHAC) will not be effective in detecting changes in the Long Valley hydrothermal system caused by geothermal development before irreversible detrimental impacts to the Hot Creek Hatchery or Hot Creek Gorge springs have occurred. The LVHAC, composed of numerous regulatory agencies and many knowledgeable geothermal resource experts, strongly disagrees with the comments made by DFG and their consultants. The consensus of LVHAC members is that DFG's consultant, Mr. Tim Durbin, is alone in his opinion that monitoring would not be effective in detecting changes prior to the onset of adverse impacts. His analysis reflects a lack of understanding of the Long Valley hydrothermal system.

The LVHAC, as an advisory group, concludes that the proposed monitoring program will be effective. The LVHAC contends that any significant change will not only be detected, but can be reversed or mitigated to a level of insignificance with respect to impacts at the Hatchery or Hot Creek Gorge springs.

The hydrothermal system monitoring program and mitigation processes embodied in the Mono County, the Bureau of Land Management (BLM), and the Division of Oil and Gas (DOG) permit conditions are designed to reduce to insignificance the possibility of impacts to sensitive hydrothermal features; primarily the Hot Creek Fish Hatchery and Hot Creek Gorge springs. Monitoring the hydrothermal system at numerous points is required to detect potentially adverse changes so that mitigation measures can be implemented before changes reach the sensitive springs. This hydrothermal system monitoring program establishes baseline data collection requirements and detects changes caused by geothermal project operations before they can affect hydrothermal features of concern. The program also provides information to permitting agencies to select and implement appropriate mitigation measures to prevent hydrothermal changes from migrating away from the production field torward the sensitive hydrothermal features and to monitor the effectiveness of implemented mitigation. The data to be collected are basically those specified by LVHAC, supplemented with some project-specific requirements additionally imposed by regulatory agencies.

The monitoring program is progressive, that is, the results of initial monitoring may prompt the establishment of additional monitoring sites and possibly the drilling of additional wells. It is designed to provide documentation of movement of hydrologic system changes away from the project areas toward features of concern.

A number of geothermal resource experts familiar with the Long Valley hydrothermal system were asked to review the Papadopulos report. A summary of their conclusions with regard to the effectiveness of the planned monitoring program and potential mitigation measures is provided below.

> U.S. Geological Survey, Michael L. Sorey: letter to the Bureau of Land Management, June 27, 1988.
>
> "A properly conceived and implemented hydrologic monitoring program should be capable of determining what the actual response is. More importantly, such monitoring provides for early detection of changes in reservoir conditions within project areas and between these areas and the thermal springs. The Papadopulos report suggests that temperature changes in thermal springs could take place only after the development period is over and hence monitoring cannot provide protection against such impacts. This situation should not occur, however, if reservoir temperature changes in and around project areas are detected by the monitoring program in the early stages of development, and suitable mitigation measures are then implemented."
>
> California Division of Oil and Gas, M.G. Mefferd (State Supervisor), letter to the Mono County Board of Supervisors, October 25, 1988.
>
> "The need for systematic hydrologic monitoring became apparent when geothermal development was proposed in the

Long Valley Caldera. The formation of the LVHAC was proposed by the Director of Energy Management of Mono County and has since been formed with representatives from the State of California, Mono County, Town of Mammoth Lakes, geothermal operators, and local developers. A subcommittee of experts has been formed and has developed a monitoring program in the area of concern, to detect any significant changes in the hydrology. The Division is a member of the subcommittee. The Division feels that the monitoring program in the area of concern will detect any significant changes and allow the permitting agencies adequate time to alleviate any problems caused by the geothermal development."

California Division of Oil and Gas, Robert S. Habel: letter to Mono County Energy Management Department, November 21, 1988.

"The Division requires monthly production/injection reports for the Casa Diablo geothermal field, and has been monitoring this data since the geothermal field first produced. This information is stored on computer and is used to evaluate field performance. Field performance may indicate possible problems in the geothermal reservoir."

"It is the Division's opinion that not only our current monitoring program, but the proposed monitoring program is very important in detecting changes in the geothermal reservoir. The changes in the reservoir may or may not effect the springs feeding the fish hatchery or Hot Creek Gorge, but we may never know if the geothermal system is not monitored. It is also the opinion of the Division, that the proposed production from the Mammoth Pacific II Power Plant will not cause changes in the geothermal reservoir which will adversely affect the springs feeding the fish hatchery or Hot Creek Gorge."

Berkeley Group, Inc., Draft PLES I Geothermal Project, Environmental Impact Statement/Environmental Impact Report Supplement, September 1988.

"A regional program for monitoring effects from existing and proposed geothermal power plants and other relevant projects has been developed by LVHAC and put into effect and, based on information obtained through monitoring programs required by the BLM, will provide guidelines for detection limits and trigger point limits which would initiate revised pumping plans, hatchery mitigation, and power plant shutdown. While monitoring will not, in and of itself, mitigate adverse cumulative impacts, it would provide an opportunity to identify hydrology changes as they occur and would allow sufficient time for appropriate remedial mitigation measures to be implemented, if necessary."

Mesquite Group, Inc., Summary Analysis of the CDF&G Papadopulos - Report, May 26, 1988.

"Monitoring of the production reservoir, whether through the production and injection wells themselves or through observation wells, such as Well No. 65-32 (drilled especially for this purpose at Casa Diablo), is designed to detect very small temperature or pressure changes. The purpose of monitoring is to observe changes in the reservoir far in advance of these changes migrating away from the production area, so that effective mitigation measures can be implemented. Neither the project operator nor the responsible regulatory agencies would allow even close to a 30 degree Celsius decline in the temperature of the production reservoir to occur without requiring the implementation of reservoir mitigation measures and the drilling of additional monitoring wells to ensure that none of the impacts predicted by this "Papadopulos" model would occur."

Mesquite Group, Inc., Comments to the Bureau of Land Management on the Draft PLES I Geothermal Project Environmental Impact Statement/Environmental Impact Report Supplement, Nov. 4, 1988.

"Drastic changes such as those predicted by the Papadopulos model would be detected at Casa Diablo itself almost immediately. Mr. Durbin fails to recognize the ability to control pressure distributions and/or temperature by reorienting production/injection patterns. He also fails to recognize the conductive reheating potential of the massive volume of hot rock between Casa Diablo and the Hatchery area."

"Papadopulos postulates that this cooled injection zone will eventually migrate with the regional flow to the Hatchery area. Migration calculations in the Draft EIS/EIR Supplement also indicate that the cooled injection zone could reach the Hatchery area in about 100 years, if the zone maintains its integrity. However, it was noted that the cooled zone could not really migrate intact, but rather would tend to sink deeper into the reservoir, and would be reheated by the hot reservoir rock as it moves from west to east."

Barnett Intermountain Water Consulting, Jack A. Barnett; letter to Mono County Energy Mangement Department, November 23, 1988.

"We write to urge you to bring to the Board of Supervisors for Mono County, and any other regulatory body that you feel appropriate, our strong belief that (1) the current monitoring program is in fact, adequate, (2) it will be effective in monitoring any changes that might occur in the hydrologic system, and (3) changes can be reversed by appropriate reservoir management practices.

We believe that assertions made to this regard by the California Department of Fish and Game and their consultant, Papadopulos, are just simply wrong. We believe that the preponderance of evidence and the opinion of all experts involved leads anyone investigating the allegations made to conclude that their assertions are not based upon an understanding of hydrologic systems, geothermal resource development, and most importantly, the hydrology of the Long Valley."

California Energy Commission, Cheryl Closson; letter to Chairman of LVHAC, March 10, 1989.

"On January 12, 1989, Mr. Durbin made a presentation on the S.S. Papadopulos work to the Long Valley Hydrologic Advisory Committee (LVHAC). The LVHAC developed the monitoring program currently being implemented by the U.S.G.S. and funded by Mono County and the California Energy Commission. At this meeting, Mr. Durbin essentially reversed his contention that monitoring would be ineffective and instead stressed the policy/decision-making end of mitigating potential impacts from geothermal development."

"The issue was shifted from the technical consideration of whether monitoring can indeed detect changes in the system, to whether the policy-makers will act on information provided to them to mitigate potential effects. This change in emphasis is significant since the monitoring program, as outlined, is completely separate from any policy actions taken by the various agencies having jurisdiction over development. The LVHAC monitoring program is meant to be, and has always been, represented as being advisory information only, to be used by the regulators in whatever manner they choose in making policy decisions."

"As a member of LVHAC, I completely support the monitoring program as a means for early detection of any changes in the hydrologic system, whether natural or in response to any development in the Long Valley Caldera. I also believe that it is imperative that the LVHAC make a formal statement in response to the S.S. Papadopolus report(s) and to Mr. Durbin's ever-changing contentions about the effectiveness of monitoring as a tool in mitigating possible effects of geothermal development in the Long Valley Caldera."

To summarize the aforementioned technical opinions on the effectiveness and importance of monitoring the hydrothermal system in Long Valley, Rob Willis (Miller and Wood Ranching), a member of the LVHAC who is not, by profession, a hydrologic expert puts the issue in a very straightforward, succinct perspective: "I feel very strongly, as I think everyone does, that monitoring is our only real means of possibly detecting changes and preventing damage. Whether we have direct proof that monitoring is effective or not, I think we have to monitor and interpret data as a measure of common sense."

The LVHAC provides the information contained herein from an advisory standpoint only. The committee acknowledges and respects your role as an agency with permitting authority over the development of geothermal resources in Mono County and, accordingly, does not request any specific action pursuant to this letter; merely that you take this information under advisement.

If you have any questions regarding this letter in particular or regarding any functions of the LVHAC in general, please contact me at (619) 934-6704.

Sincerely,

Dan Lyster

Dan Lyster
Chairman, LVHAC

cc: LVHAC Members

DL/djh

4.7.5.c

Mesquite Group, Inc.

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JUN 23 1988

FILE COPY

May 26, 1988

Mr. Donald C. Liddell
Special Counsel
Pacific Enterprises
6055 East Washington Boulevard
Commerce, California 90040

Subject: Analysis of Report "Evaluation of Impacts of Geothermal Development Within Long Valley", prepared for California Department of Fish and Game by S. S. Papadopulos & Associates, Inc., dated May 9, 1988.

Dear Don:

In response to your request of last Friday, Mesquite Group, Inc. has reviewed the subject report and offers three levels of comment. The first attachment is a summary discussion of what we consider to be major flaws in the report's basic premises and conclusions. The second attachment is a paragraph-by-paragraph, detailed critique highlighting all the statements (minor and major) in the report which we believe deserve comment or correction. The discussion which follows provides an overview of our analysis:

(a) The Papadopulos report employs a simple energy balance model of the Long Valley geothermal system which is quite different from the models used by other investigators.

(b) The report's principal conclusion, that the heat in the system will be severely depleted by the planned geothermal development, is meaningless because numerous erroneous assumptions are used in defining the model and because the calculations are carried to unrealistic extremes.

(c) The heat storage assumed for the modeled geothermal system is extremely small, 186 times smaller than the U. S. Geological Survey estimate for the Long Valley caldera. Correcting this assumption alone changes the model's predictions such that a maximum decline of only 2.0°C in Casa Diablo reservoir temperature is predicted, which would result in no discernable effect on the Fish Hatchery springs or the Hot Creek gorge springs.

(d) The heat inflow to the system allowed in the model is limited to the equivalent of the current outflow from the springs at the Hatchery and Hot Creek. This is also unrealistically small.

(e) The "predicted" 150°C temperature decline of the Casa Diablo reservoir fails to recognize that the power plants would become uneconomical to operate after a 30±°C decline, and, if the model were correct, would be shut down after only four years of operations. Correcting this misconception would reduce the model's "predicted" reservoir temperature declines at the fish hatchery by a factor of five, to only 1.4 or 6.8°C. (However, note that a temperature decline at the hatchery reservoir would result in only a fractionally small change in the temperature of the Hot Creek headsprings supplying the hatchery. See comment (g) below).

(f) This same modeling would "predict" that the existing Mammoth-Pacific Unit I would have already produced a 6°C temperature decline in the Casa Diablo reservoir during its four years of operation when, in fact, no decline in reservoir temperature has occurred.

(g) The implied worst-case 34°C temperature decline of the springs at the Fish Hatchery is impossible because the hottest spring flows at only 16°C, and fails to recognize that the geothermal component of the springs is only 2 to 5 percent. The correct interpretation of the predicted worst-case temperature change of the Fish Hatchery springs is only 0.7°C to 1.7°C. (However, note that these temperature changes occur only if the lack of validity of the heat storage and inflow assumptions of the modelers is ignored. See comments (c) and (d) above.)

(h) The report's contention that monitoring will not detect adverse impacts until irreversible changes have begun at the Hatchery fails to recognize that monitoring at the source (i.e., Casa Diablo) will detect very small changes at the source, and that any significant temperature decline will be mitigated in the field long before changes of the magnitude predicted by the model are allowed.

In conclusion, we believe the Papadopulos report employs a simplistic model of the Long Valley geothermal system which utilizes erroneous assumptions and carries the calculations to absurd extremes. As a consequence, its predictions of significant heat depletion due to geothermal development are meaningless. If the input data and assumptions were "corrected", the results would predict no discernable impact to the Fish Hatchery from operation of the Casa Diablo geothermal projects.

In our opinion, there is still enough uncertainty about critical parameters that the ability of such a simple model to accurately reflect the Long Valley geothermal system is highly suspect. Those of us (including Dr. Sorey) who are much more familiar with the Long Valley geothermal system, and familiar with more complex heat balance models (thermal simulators), do not believe we can create a definitive model as yet. Only additional production experience and monitoring will allow us to obtain the necessary data to construct a credible numerical model of the entire Long Valley geothermal system.

Sincerely,

Don A. Campbell

(IB) for Don A. Campbell

DAC:cv

Attachments (2)

cc: Owen Olpin, O'Melveny & Myers
Todd Littleworth, Pacific Enterprises
Dwight Carey, Environmental Management Associates, Inc.
Mike Walker, Pacific Energy

MESQUITE GROUP, INC.'S
SUMMARY ANALYSIS OF THE REPORT
"EVALUATION OF IMPACTS OF GEOTHERMAL DEVELOPMENT WITHIN LONG VALLEY"

(Prepared for California Department of Fish and Game
by S.S. Papadopulos & Associates, Inc., May 9, 1988)

May 26, 1988

The underlying premise for this report's energy balance model of the Long Valley geothermal "system" is quite simple, i.e., the change in the quantity of heat stored in the system is equal to the rate of heat inflow into the system minus the rate of heat extracted from the system. This approach is very different from that used by prior investigators of this problem, but theoretically could be valid if appropriate model constraints and inputs are used. However, because of numerous erroneous assumptions used to define the geothermal system for the model, and because of the extremes to which the calculations are taken, the results of the modeling effort are meaningless and, worse, very misleading.

The Papadopulos modelers assume, without explanation, that the Long Valley geothermal system has a total volume of $3.55 \times 10^9 m^3$ (Table 2). Given their stated assumption regarding the average temperature of the system, and an assumed porosity and heat capacity of the rock (which are not stated), the total stored heat which can be extracted from the system is purported to be only 1×10^{17} calories (page 2). The modelers also run a second case in which they assume that the "available" reservoir in three of the four blocks in the model is only ten percent of that used in the first case, or $1.43 \times 10^9 m^3$ (which results in a total of only 0.40×10^{17} calories in storage) (page 20). For both cases, they assume that the only heat available to recharge the geothermal system is that quantity of heat which is currently estimated to be discharged by the Hot Creek Fish Hatchery and Hot Creek gorge springs (page 19).

Taken together, these two assumptions produce a modeled result which has no validity. First, the "modeled" available heat in storage assumed is extremely small. The U.S. Geological Survey (USGS), in Circular 790, estimated that the mean reservoir thermal energy of the Long Valley caldera was 186×10^{17} calories, or 186 times that said to be available by Papadopulos. The USGS value is based on a mean reservoir volume for the caldera of $136 \times 10^9 m^3$, nearly 40 times that assumed for the basic model. If the USGS estimate of wellhead thermal energy is compared to the report's second case, the result (46×10^{17} calories) is still 115 times the stored heat assumed by the modelers. Circular 790 also specifically states that the estimates of heat in the reservoir do "not consider possible resupply of heat from below or from the sides.... and are thus considered minima" (page 19).

The modelers' decision to limit the heat available for recharge of the system to that heat which currently leaks out of in the form of thermal springs, while also severely limiting the size of the geothermal reservoir, clearly produces a result which conflicts with the available data for Long Valley as well as most other commercially developed geothermal reservoirs in the world. Classic geothermal convection systems involve the upward flow of heated water, usually along faults, which spreads out laterally once it reaches a permeable horizontal zone, eventually sinking at some distance from the upward plume as it cools. Cooling occurs because of conductive heat losses to surrounding water and rock, mixing with cooler waters and, sometimes, boiling at discharge points. Such a system need not have any discharge of geothermal fluid in order to sustain substantial convective flow, and the system may have the potential for very substantial flows even if it is essentially static. All that is required is the imposition of a pressure release point, such as a well. Many of the major commercially developed geothermal reservoirs in the world had little or no thermal fluid discharge prior to development. If their thermal energy recharge was limited to pre-existing thermal spring discharges, then most of these reservoirs would have been exhausted long ago. The point is that by both limiting the size of the system and limiting the recharge of heat to the system to that discharged by a few of the existing thermal springs, the heat available for consumption is quite small. Realistically, the model must either allow for the influx of substantially more heat to the producing reservoir from below and/or the sides, or the reservoir must be expanded to include this additional reservoir within the system model. In either case, the resulting "corrections" for Long Valley would dramatically reduce the "predicted" rate of temperature decline in the reservoir. Using the values for heat in place of the previous paragraph, the model would predict temperature declines in the Casa Diablo reservoir after 30 years of operation (the economic life of the project) of only 1.2 to 2.0°C, which would result in no discernable change in the temperature of the reservoir under the Fish Hatchery or Hot Creek gorge.

The implausible assumptions used in the modeling exercise are compounded by running the model to extremes, with the result that very misleading conclusions are reached. For example, the Casa Diablo cases (see Figures 4 and 5) predict that after only 20 years, the temperature of the Casa Diablo geothermal reservoir would decline in temperature by 150°C! The reality is that a 30±°C degree decline in reservoir temperature would make the plants uneconomic to operate and they would be shut down (after only four years of operation under the model). If this were to occur (which we do not predict), the model would predict temperature declines in "Block 4" (the Fish Hatchery) of less than 1.4°C (Figure 4 case) or 6.8°C (Figure 5 case) after 150 years.

Even assuming that the model correctly predicts responses (which is clearly not the case), the modelers imply that the springs at the Fish Hatchery will decline a maximum of 34°C in temperature. Since the hottest spring at the Hatchery (AB) is only 16°C and the normal cold springs are about 11°C, a 34°C decline is obviously impossible. More realistically, the model predicts a maximum 34°C decline in the underlying geothermal reservoir. Since the average geothermal water contribution to the Hatchery springs flow is two to five percent, the average predicted temperature decline of the springs even under this worst case would be only 0.7 to 1.7°C. If the plants stopped operating after a 30°C temperature decline at Casa Diablo, then the model would predict a maximum decline in the Fish Hatchery springs of only 0.1 to 0.3°C. For the reasons given in the paragraph above, we clearly do not believe that the temperature of the Casa Diablo reservoir will decline by 30°C, and thus do not believe that even this small change in the Hatchery Springs will occur.

Both cases modeled indicate that the Mammoth Pacific I project should already have caused a 6°C decline at Casa Diablo. This has not happened, of course, and further demonstrates the invalid nature of the model. The first rule of numerical modeling is to "history match" actual experience. If the model cannot match the actual, then predictions from it are meaningless.

Finally, the report's statement that "Monitoring will not detect adverse impacts until after irreversible changes have begun to occur (page 21)" is also unrealistic. Monitoring of the production reservoir, either through the production and injection wells themselves or through observation wells, such as Well No. 65-32 (drilled especially for this purpose at Casa Diablo), is designed to detect very small temperature or pressure changes. The purpose of monitoring is to observe changes in the reservoir far in advance of these changes migrating away from the production area, so that effective mitigation measures can be implemented. Neither the project operator nor the responsible regulatory agencies would allow even close to a 30°C decline in the temperature of the production reservoir to occur without requiring the implementation of reservoir mitigation measures and the drilling of additional monitoring wells to ensure that none of the impacts "predicted" by this model would occur.

In summary, the report presents a very simple energy balance model of the Long Valley geothermal system which produces meaningless results because it uses erroneous assumptions regarding the heat stored in the geothermal reservoir and the available heat recharge to the system, and because the modeling calculations are carried to implausible extremes. In addition, the report's statement that monitoring would not be able to detect changes in the reservoir until it was too late to protect the Hot Creek Fish Hatchery is equally invalid, in that it presupposes that temperature changes much greater than those which would force the abandonment of the project would be completely ignored by the operators and regulatory agencies. Both these parties would implement mitigation measures long before the predicted temperature decline could actually occur.

MESQUITE CRITIQUE OF "EVALUATION OF IMPACTS OF GEOTHERMAL DEVELOPMENT WITHIN LONG VALLEY"
(as Prepared for California Department of Fish and Game
by S.S. Papadopulos & Associates, Inc., May 9, 1988)

May 26, 1988

Page	Paragraph	Report Statement	Mesquite Comment or Correction
1	1	MP I on line in 1985	Actually 1984
1	2	"water will be injected back into the geothermal reservoir"	A fundamental premise of the model is that the injected water cools the prodution reservoir. This is not really so at Casa Diablo - Hydraulic communication is believed to exist, but residual cooled water is actually injected below the production interval - There is currently no pressure gradient sufficient to cause injected water to return to the production reservoir - Direct injection of cooled residual water into fractured geothermal reservoirs is almost always avoided (world wide) due to the potential for early breakthrough

Page	Paragraph	Report Statement	Mesquite Comment or Correction
2	2	Natural heat replenishment = 5.0 x 10^7 cal/sec (Sorey, 1975)	Cannot find Sorey, 1975 reference - Sorey, 1976 states number is 6.9 x 10^7 cal/sec - This is only the surface discharge rate based on Lake Crowley chemistry, an indirect measurement subject to considerable uncertainty - It is probably a minimum, but does not account for much larger conductive losses to cold groundwaters and rock, any "downward legs" of convection cells and losses out of the Caldera - It has no direct relationship to heat available for production in the Caldera
2	2	Stored heat = 1 x 10^{17} cal.	Unable to locate source for this number, but probably is near - surface only (i.e., the lateral flow portion of the lateral flow model) - It probably does not consider heat in the deep/western "parent" resource - U.S.G.S. number is 186 times as great for Long Valley
2	2	Potential yield is 1.5 x 10^8 cal/s	Should be 1.6 x 10^8 cal/s

Page	Paragraph	Report Statement	Mesquite Comment or Correction
3	1	Site-specific studies of project areas and how they fit into and interact with the regional system have not been made	There are more than 100 technical papers published concerning the Long Valley hydrothermal system, many of which relate specific Casa Diablo and Mammoth Chance data to the system - The author(s) do not appear to be familiar with the literature data base, citing only the EIR's and two early Sorey references for data (Sorey, 1985 is also referenced, but not apparently used)
7	1	"The crest of the dome is down faulted into a graben by northwest trending faults"	There are at least three and possibly four major grabens transcending the dome - The authors ignore these structural barriers to flow except to justify reducing the effective reservoir volume in the model when it suits them
7	2	Bishop Tuff thickness ranges from 0.5 km in the southwest to 2.5 km in the north and northwest	Tuff is about 1400 m thick at RGI 66-29 (southeast central Caldera), 900 m thick at Casa Diablo, and 400 m thick at Union 44-16 (western Caldera)

Page	Paragraph	Report Statement	Mesquite Comments or Correction
7	2	Average bulk porosity of upper two units is 0.35	This is much too high for these types of rocks - The rhyolites at Casa Diablo have virtually no matrix porosity and probably less than 10% fracture porosity - An assumption of porosity this high is required to reproduce the heat content values of the model
8	3	Entire "Faulting" discussion	Does not recognize the predominance of Basin and Range type normal faulting (horsts and grabens) which pervade the Caldera

Page	Paragraph	Report Statement	Mesquite Comment or Correction
9	1	Entire paragraph	This is outdated description of lateral flow model - Current model expressed by attached Figure (Sorey, 1987) includes upwelling from deep western source region
9	1	Thermal waters flow within upper unit and discharge either as spring flow or subsurface inflow to Crowley	Lateral flow model (old and current) includes downward convection of cooled thermal waters - Not all thermal waters discharge in anyone's model (except Papadopulos') - No credit is given for subsurface inflow to Crowley in the modeling
9	2	0.25 m^3/s or 5.0 x 10^7 cal/s discharge	Same comment as page 2, paragraph 2 - Farrar, 1986 gives number of $0.25 m^3/s$ for Hot Creek Gorge springs alone - There is additional substantial discharge between Hot Creek and Crowley

Page	Paragraph	Report Statement	Mesquite Comments or Correction
10	1	"The "isolated system" conceptual model is implausible"	It is apparent that the author(s) have no clear idea of what constitutes the "lateral flow" model versus the "isolated system" model, as they freely intermix features of both to suit elsewhere in their report - The author(s) apparently read the draft EIR (BGI's Appendix), but do not appear to be familiar with the final DEIR written comments submitted by PEn (GeothermEx, Cascadia, Mesquite) favoring the "isolated system" model - Calling something "implausible" does not constitute proof or evidence

Page	Paragraph	Report Statement	Mesquite Comments or Correction
11	1	"Implausible or troublesome postulations" must be made to reject the "logic" that project thermal waters must eventually migrate to Hot Creek	(1) Discharge of thermal waters may occur not only via surface springs, but may dissipate through conductive heat losses to rock and colder waters, may mix with colder water, may boil, may sink as the downward cooled leg of a convection cell and may leak through the southern Caldera boundary towards Bishop (via Rock Creek and the Bishop Tuff) - (2) Thermal waters must move by a very circuitous path to yield the temperature distributions seen at Casa Diablo and Mammoth Chance - (3) Three convective cells (i.e., "isolated systems"), each confined to a graben (Casa Diablo, Mammoth Chance, Hot Creek) actually fit the observed data quite well in Mesquite's opinion

Page	Paragraph	Report Statement	Mesquite Comments or Correction
11	2	Entire paragraph	Natural convective geothermal systems in the classic case have both upflow (hot water) and downflow (cooled water) regions, and no surface discharge is required - Some geothermal reservoirs are essentially static (except for conductive heat fluxes), having potential for flow, but not actually flowing at significant rates until pressure is decreased at some point, say by drilling a well - At Casa Diablo heat is discharged at the surface by conduction and by MP I production, the Casa Diablo Geyser, Meadow spring, Colton spring and several other springs and fumarolic flows. Additional heat is lost to surrounding colder waters and rock, and probably convects downward within the Casa Diablo Graben in an "isolated system" - It does not have to flow laterally to Hot Creek - The 4 x 10^5 cal/s local heat discharge value is unsubstantiated by reference, but has no significance anyway

Page	Paragraph	Report Statement	Mesquite Comments or Correction
13-17	All	Entire model	Technically correct for the most part, but only works if the correct input values and constraints are used - There is no requirement that surface outflow equal total inflow in geothermal systems: it is a minimum, but not a maximum - Ignores conductive heat fluxes to and from rock and water surrounding the reservoir - As formulated, the author(s)' equations are not quite correct because the temperature values (T_R, T_{IW}, T_{p1}, T_{p2}) would have to be input in degrees Kelvin; to use degrees Celsius, the temperature terms would have to incorporate a reference temperature; in practice this is what the author(s) have done, using 0°C as the reference temperature

Page	Paragraph	Report Statement	Mesquite Comments or Correction
17	1	Last reservoir (Block 4) includes Fish Hatchery springs	Warm springs at the Hatchery are actually in Block 3
18	1	Blocks 2, 3, 4 receive heat from local upward convection as well as lateral inflow originating from Block 1 (Casa Diablo)	These assumptions mix features of the "lateral flow" model with those of the "isolated system" model - If the authors want to subscribe to the lateral flow model then the "correct" assumption would be that all the heat flows first into Block 1 and then laterally into each successive block
19	1	Table 2	There are no 200°C temperatures in the Caldera east of Shady Rest - Casa Diablo (Block 1) should be 170°C and each successive block should be colder

Page	Paragraph	Report Statement	Mesquite Comments or Correction
19	1	Reservoir thickness of 300 m	Casa Diablo reservoir is about 100 m thick - The shallow hydrothermal reservoir system further east is poorly defined, but probably is less that 100 m thick everywhere - A thicker reservoir would have to incorporate the hot intervals in the underlying Bishop Tuff, but these intervals definitely do not constitute the production source at Casa Diablo
19	1	"The total upward water inflow equals the total spring discharge listed in Table 3 because the cumulative upward inflows equal the local spring discharge"	This is a fundamental misconception (for all the reasons previously stated) which forces the model to its negative conclusion - Obviously if you take heat out of the system at a much higher rate than you allow it to flow in and you assume a small initial storage (relative to the extraction rate), the system will cool off - It is more reasonable and in keeping with the evidence to date to assume that pressure drawdown due to production will cause a compensating increase in convective inflow to Block 1

Page	Paragraph	Report Statement	Mesquite Comments or Correction
19	1	"Water inflow is assumed to be distributed equally to the individual reservoir blocks"	See comment page 18, paragraph 1
19	1	Table 3	The upflow volume used equals that attributed by the author to the Hot Creek and Fish Hatchery springs - What happened to Casa Diablo Geyser, Meadow, Colton and the "large" underground flow to Crawley?
20	1	Figure 4, "production was terminated after 20 years because of excessive decline in average reservoir temperature"	In reality, if the temperature declined this much the power plants would shut down in about 4 years, after a 30±°C decline (not a 150°C decline) - This would obviously eliminate most of the downstream effects (i.e., Block 4 would change less that 1.5°C) - Also implies that MP I alone should have caused a 6°C decline at Casa Diablo already.

Page	Paragraph	Report Statement	Mesquite Comments or Correction
20	2	"Thermal waters occur within limited depth intervals .... and may be confined laterally within faults"	If the faults are confining and basically run north-south, how does water travel laterally from block to block in the model? This "isolated system" concept was used by the author(s) to justify reducing the block size in what is essentially a "lateral flow" model
20	2	"Temperature predictions were made for the case where the reservoir volumes for Blocks 2, 3, and 4 were 10 percent of those indicated in Table 2	Why was Block 1 also not reduced? It is actually more realistic to reduce all of them, but reducing Block 1 would probably have resulted in such an immediate precipitous decline in temperature at Casa Diablo that the unreasonableness of the other assumptions would have been obvious to the casual reader
21	1	Figure 5	See comments page 20, paragraph 1 - A 34°C decline in the hydrothermal reservoir at the Hatchery (Block 4) does not translate to a 34°C decline in "Hatchery" spring temperature - only 2±% of Hatchery spring flow is geothermal

Page	Paragraph	Report Statement	Mesquite Comments or Correction
21	2	"Monitoring will not detect adverse impacts until after irreversible changes have begun to occur"	Monitoring in Block 1 would detect such extreme changes almost immediately
24, 25	All	All conclusions	Totally meaningless because of the simplistic nature of the model and the many erroneous input assumptions
Table 1	N/A	MP I Heat Extraction = 1.4 x 10^7 cal/s	Should be 2.4 x 10^7 cal/s
Table 2	N/A	Upward water inflow (m^3/s) = 13.00 x 10^{-2}	Should be 14.4 x 10^{-2} m^3/s if derived from Table 3 130 kg/s (specific gravity of 200°C water is about 0.9, not 1.0)
Table 3	N/A	Springs in Hat Creek gorge Heat Discharge (cal/g)	Should be Hot Creek and (cal/s)

cc. D. Campbell

JUN 20 1988

bgi

Berkeley Group Incorporated

RECEIVED
JUN - 6 1988
D. C. LIDDELL

June 3, 1988

Don Liddell
PLES
6055 East Washington Blvd.
Commerce, CA 90040

Dear Don:

I have talked with Don Campbell about the Papadapoulous & Associates Report, and he indicated that you would like to have a short critique from us also.

You asked for my opinion about PAI. My experience with Stavros Papadopoulous is limited, but I have always held him in high regard technically. I do not know the people in the Davis, CA office and have never seen any of their technical geothermal publications, if they have any.

Our critique including my modeling qualifications, and an invoice are attached. If you have any questions or wish to discuss the report further, please don't hesitate to call.

Best Regards,

Ron Schroeder

R.C. Schroeder

RCS/sc

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Memorandum:

June 3, 1988

Critique of "Evaluation of Impacts of Geothermal Development Within Long Valley", by S.S. Papadopoulous and Associates Inc. May 9, 1988

General

The Papadopoulous & Assoc. Inc. (PAI) model is overly simplistic, uses numerous incorrect assumptions, and has several specific errors in the data. The three basic assumptions in the report are:

1. The heat budget of the southern caldera is given by the amount of heat that is lost to surface springs by convection.
2. The Long Valley geothermal system is defined by rectangles shown in the author's Figure 3, with thickness of 300 meters.
3. The behavior of the geothermal system can be characterized by the average temperatures of the PAI rectangular volumes.

None of these assumptions is meaningful for analysis of production and injection of geothermal fluids.

The comment that "Berkeley Group describes a conceptual model that consists of an isolated local geothermal system" is wrong in fact and substance. Our models utilized infinite reservoir assumptions. However, we correctly examined local effects of production of hot fluids and injection of cool fluids. We also recognized the limitations of such models and the probability of local convection within fault controlled regions.

The question posed by PAI in their report "... where does the heat and water discharge ..." suggests a lack of experience in analyzing the evolution of hydrothermal systems, particularly when major faults exist. Their total neglect of the heat budget available from the reservoir rocks during re-injection further indicates their lack of understanding of the physics of geothermal systems. Their use of average reservoir temperatures over large volumes to analyze the behavior of the system during localized production and injection is totally inadequate.

The authors discuss the geologic history of the region, apparently to indicate their knowledge of the area, but they put that local and regional geological, stratigraphic and structural data to no use in their modeling. Likewise, with the exception of the previously published data on spring discharge values, they use only generalized hydrologic information in the definition of their model. This may be the reason for their incorrect contention that the temperature of the Fish Hatchery Springs is directly related to the geothermal reservoir average temperature. Their use of Sorey's estimate for recharge to their rectangular volumes constitutes the smallest possible value that anyone would conceivably use.

Considerable time, effort, and funds have been expended by a number of government agencies and private companies in analyzing the evolution and present state of the Long Valley hydrothermal system (1-7), the potential for generating power from the resource, and the likely environmental effects of such power production (8, 9, 10). The PAI report has not been prepared with a comparable amount of effort or expertise.

Particular

In addition to the erroneous assumptions previously referred to, there are numerous specific errors of fact or omission. The number used for surface discharge of heat given by Sorey should be 6.9×10^7 cal/s, not 5×10^7 (2). A value of 0.35 for the porosity of any of the lithologic units in Long Valley is much too high.

The heat yield from a geothermal reservoir during production and injection is primarily dependent upon the heat stored in the local reservoir rocks, not the surficial heat discharge from the regional system. The 1.1×10^8 Cal/s calculated by PAI is irrelevant in an analysis of power production. If a surficial heat balance determined potential power production, then none of the existing major geothermal power plants could have operated. As examples consider (11, 12, 13).

	MWe	Yrs in operation	
Wairakei	< 160	25	
Geysers	<2000	25	
Larderello	> 365	20	
Cerro Prieto	> 200	10	
Matskawa	> 20	27	
Reykyavik	> 10	55	(used primarily for direct heat)

None of these resources have had surficial heat discharge that even approximates the amount of heat removed for production of geothermal power. PAI has grossly underestimated the amount of heat available for power production by neglecting stored heat in the rocks, cooling of fluids as they move through lower temperature rocks to surface springs, and movement along and within faults.

PAI assumes a lateral flow model and does not take into account known faults and their effects on the geothermal system. Mike Sorey of the USGS has indicated that the simplistic lateral flow model is not adequate (14). The upwelling of hot fluid along the faults that run perpendicular to the assumed lateral flow direction contributes a major amount of fluid to the present MP I power plant. This major source of recharge maintains the current plant (approximately 8 MW) with no measureable temperature or pressure decrease, which is ignored by PAI. It is circulation in the major faults that must be included in any heat balance model - i.e., upwelling of hot fluid along some faults and sinking of cooled fluid along others. It is the vertical convection of fluids that plays a major role in all liquid-dominated geothermal systems. As D. White of the USGS has correctly noted, "Hot springs are a common but not universal indication of hot-water convection systems" (15).

Qualifications (R.C. Schroeder)

Geothermal resource research, 1972 to present.

Leader of Geothermal Reservoir Research group 1975-1980 (LBL).

Geothermal Resource Consultant, 1980 to present.

Developed heat depletion model for geothermal reservoir with both porous and fractured rocks (with P. Kasameyer) (1973 to 1975).

Developed finite difference model for heat transfer with scale deposition (1974).

Developed distributed two-phase geothermal reservoir simulators SHAFT78, SHAFT79 (with K. Pruess and others, 1975 to 1981).

Developed two-phase wellbore simulation models for both steady state and transient flow (with C. Miller and others, 1976 to present).

Developed multiple feedpoint model for analysis of two-phase geothermal reservoirs and wellbore logs (1987 to present).

Developed analysis models for transient geothermal well testing (1975 to present).

Developed anisotropic model for analysis of geothermal reservoir tracer tests (1986 to present).

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United States Department of the Interior
GEOLOGICAL SURVEY

COPY

June 27, 1988

Comments on "Evaluation of Geothermal Development within Long Valley" - a Report by S.S. Papadopulos & Associates, Inc.

Michael L. Sorey
U.S. Geological Survey
Menlo Park, California

At the request of the Bureau of Land Management's Sacramento office, I have reviewed the report cited above. My comments on this report and on the related issues of 1) the effectiveness of hydrologic monitoring in detecting changes in the hydrothermal system due to geothermal production and 2) the effectiveness of proposed mitigation measures to prevent or reduce impacts of geothermal development to acceptable levels are given below.

Papadopulos Report

This report presents an analysis of the changes in stored heat and temperature in part of the Long Valley hydrothermal system between Casa Diablo and the Hot Creek Fish Hatchery resulting from geothermal production at 47 MW over a 20-year period. An energy balance approach is used in which changes in stored heat are computed from the difference between convective heat input and output and net heat outflow from geothermal power production. A continuous reservoir 300 m thick is assumed to extend between Casa Diablo and the Fish Hatchery and this region is subdivided into four blocks, each 300 m thick, for calculating changes in reservoir temperature with time. Hot water inflow to Block #1 at Casa Diablo is set equal to 32.5 L/s at 200°; inflow to each of the other blocks equals 32.5 L/s at 200°C plus the cumulative inflow to the adjacent blocks to the west at temperatures that decline with time with the average temperature of each block. The total hot water inflow to and outflow from the four-block model is thus 130 L/s. The principal conclusions of the report are 1) that heat extraction for geothermal power production at Casa Diablo and Chance Springs (Meadow) will cause large reservoir temperature changes in the production areas (up to 150°C after 20 years) and significant reservoir temperature changes beneath the Fish Hatchery (7° to 67°C after 75 years) and 2) that hydrologic monitoring could not detect adverse impacts before irreversible changes have been created.

To begin with, there is nothing inherently wrong with the energy balance approach utilized in this report. Indeed, the general conclusion that geothermal power production at rates proposed for Long Valley would cause large reservoir temperature declines, in the absence of significant induced inflow of hot water from adjacent regions, is in fact valid. Reference to this matter was made in the EIR for the Mammoth/Chance project (p. 3-32) in terms of a personal communication from me to the affect that only 3 percent of the required heat for the project is stored in the production reservoir beneath the project area. Furthermore, significant changes in reservoir pressure may not occur during development if pressure support is provided by reinjection of produced fluids, but there remains an energy deficit that will cause significant temperature declines unless alleviated by induced inflow of hot water.

The effect of such induced inflow would be to supply heat to the project area from other parts of the geothermal system. Calculations presented on p.2 of the Papadopulos report suggest that even if this were to occur, the potential yield of the geothermal system (1.5×10^8 cal/s from natural convective heat discharge and recoverable heat in storage) is approximately equal to the net heat production rate for the total proposed electric power production of 47 MW, and thus significant impacts to the natural geothermal system are inevitable. Unfortunately, no justification is given for the assumed 1×10^{17} cal of "stored heat that could be mined [by development]". Although published estimates of about 50×10^{17} cal for recoverable heat in the Long Valley geothermal system (Muffler and Williams, 1976; Muffler, 1979) are probably unreasonably large, a more realistic estimate based on recent drilling data from the west moat of the caldera would be about 10 times larger than the value noted in the Papadopulos report.

The controversy that has developed over the impacts of geothermal development on thermal springs at the Fish Hatchery and Hot Creek gorge is due in large part to uncertainty regarding both the degree to which thermal areas between Casa Diablo and Hot Creek gorge are hydrologically connected and the response to development of the geothermal system in the vicinity of each project area. At this stage, no one knows for sure if there is in effect a continuous thermal reservoir between Casa Diablo and Hot Creek gorge or if proposed geothermal developments will induce inflow of hot water from reservoirs at greater depths and/or capture the natural throughflow of thermal water at relatively shallow depths. Answers to these questions are needed before we can predict the magnitude of changes in temperature, pressure, and spring flow rates that could be induced by development. For example, if hot water inflow should occur at Casa Diablo at rates equal to or greater than the natural throughflow rate of 250 L/s (see Sorey and Lewis, 1976; or Papadopulos report, p. 9), temperature drops calculated for Block 1 by the method used in the Papadopulos report would be considerably less than the 150°C value calculated for an inflow of 32.5 L/s.

Potential impacts of geothermal development on thermal springs are best discussed under three possible scenarios that could accompany development. Under scenario (1), there is a natural throughflow of hot water at about 250 L/s moving through the volcanic section between Casa Diablo and Hot Creek gorge. Development at Casa Diablo (and Mammoth/Chance) would lower reservoir pressures sufficiently to capture all the natural throughflow (i.e. redirect it from the thermal springs to the production wells). The resultant reservoir temperature decline in each project area would be considerably less than calculated by Papadopulos & Associates, as discussed above. However, capture of the natural throughflow could result in pressure declines in the vicinity of the thermal springs with resultant declines in spring flow, unless injection wells were located and completed so as to maintain pre-development reservoir pressures near the margins of the project area. Migration of relatively cool injected water toward the thermal springs could eventually cause declines in reservoir temperature beneath the springs. An analysis of this process, included in Appendix I of the joint

EIR/EA for the MP II and MP III projects, suggested that "breakthrough of cool injected fluid is not likely to be a potential threat to existing springs", but the analysis was admittedly very approximate and limited by lack of knowledge of reservoir flow paths. Application of the method used by Papadolpulos & Associates, in which reservoir cooling near the Hatchery results from a decline in the temperature of fluid flow toward the Hatchery from the west, would suggest that cooling of the Hatchery springs could eventually occur under this scenario.

Under scenario (2), the natural throughflow is unaffected by development (or does not exist within a simple lateral flow system at shallow depths), but significant quantities of fluid and heat are induced to flow upward from a deep reservoir beneath the volcanic section into the project area. This is more or less the scenario postulated by the developer at Casa Diablo. This results in the minimum possible impacts at Casa Diablo and at the thermal springs. Using, for example, a value for the recoverable thermal energy in the geothermal system within the southwestern part of the caldera that is ten times the heat stored in Block 1 of the Papadopulos model, the calculated temperature drop in Block 1 assuming this heat could be captured would be only 15°C after 20 years (all other conditions being the same as in the Papadopulos model).

Scenario (3) would be the case assumed in the Papadopulos report - no capture of natural throughflow or heat stored in surrounding regions. Development under these conditions results in the maximum possible declines in reservoir temperature, both in the project areas and beneath the thermal springs. One qualifying point that should be noted is that because the thermal fluid component in the Hatchery springs is small (only a few percent), a given change in the temperature of the thermal reservoir supplying the Hatchery would not cause an identical change in the temperature of the springs. For example, a 30°C change in reservoir temperature should cause about a 1°C change in spring temperature.

Clearly the nature of the response of the geothermal system to development will play an important role in determining the impacts of development on thermal springs. Because this response cannot be adequately predicted at the present time, a prudent course of action has been recommended. This is to set up a monitoring program to accompany development that is capable of detecting changes in the system before they become large and irreversible, and to require mitigation measures in the event that changes are detected by the monitoring program. Measurements of pressure and temperature in production and injection wells are considered part of the monitoring program. Changes in these parameters should provide the first indications that changes in the geothermal system are being induced. Indeed, it is inconceivable that with such monitoring, temperature declines in project areas as large as those postulated in the Papadopulos report could go unnoticed or that significant alteration or cessation in the development scheme would not have been put into effect long before temperature changes became that large. In addition, the most immediate effect of a net energy withdrawl in the project areas should be breakthrough of cooler injected water in production wells. This would occur long before temperature declines occur in the vicinity of the thermal springs. Should an EIS be prepared for the proposed development at Casa Diablo, the issue of reservoir temperature changes within the project area deserves more discussion and analysis than that given so far in Appendix I of the Joint EIR/EA for the MP II and MP III projects.

Effectiveness of the Hydrologic Monitoring Program

A hydrologic monitoring program has been developed by the U.S. Geological Survey, in collaboration with the Long Valley Hydrologic Advisory Committee, to detect impacts of both geothermal and nonthermal groundwater development projects on springs at the Fish Hatchery and Hot Creek gorge. The program became operational on June 1, 1988, with funding provided initially by Mono County. With regard to the existing and proposed geothermal projects at Casa Diablo, this monitoring program covers all aspects of the Plan for Baseline Monitoring approved by the BLM that apply to hydrologic issues, except for compilations of existing data, monitoring of CD supply springs at the Fish Hatchery, and collection of sediment data in streams.

The key elements of the monitoring program are frequent measurements of the discharge characteristics of thermal springs (flow rate, temperature, chemistry) and pressure and temperature in observation wells. The most difficult part of setting up the program is the completion of suitable observation wells. The criteria for such wells is that they be in hydrologic communication with production and injection reservoirs and located between the development field and the thermal springs. Logically, observation wells should first be drilled near the downstream margins of the development field. If no changes attributable to development were found in these wells, additional observation wells would not be needed. If changes were detected and mitigation measures such a relocating production or injection wells failed to reverse these changes, additional observation wells would have to be drilled closer to the thermal springs.

The existing monitoring program includes one observation well (66-32) drilled to a depth of 250 ft at the southeastern edge of the Casa Diablo project area. Although temperature, pressure, and fluid chemical data indicate that this well is in hydrologic communication with the production zone at Casa Diablo (400 to 700 ft), an additional well is needed at this location that taps the deeper injection interval (1000 to 2000 ft), along with well tests to determine the degree of hydrologic connection between both wells and the production and injection wells. Similar requirements for observation well completion and reservoir testing for the Mammoth/Chance project were described in my comments to Dan Lystar, Mono County Energy Management Department, dated January 4, 1988 (copy enclosed).

Successful operation of the monitoring program requires cooperative efforts by the developers, the regulatory agencies, and the agency responsible for conducting and reported on the monitoring. Proper interpretation of monitoring data to discern natural variations from those induced by development may require considerable hydrologic expertise and involve debate between experts. Little experience is available from other areas that could be used to access the likelihood of success of this effort.

We do have the record of over three years of operation of the MP I plant at Casa Diablo during which time no impacts to thermal springs at the Fish Hatchery or Hot Creek gorge have been detected by measurements made by the U.S. Geological Survey. The system response to that development appears to involve no significant decline in reservoir pressure, either due to pressure maintainance by reinjection or the presence of a constant pressure boundary such as a fault that connects the production zone with a deeper, more permeable reservoir. Temperature declines in the vicinity of the injection wells are large (30^0 - 70^0C), but the position of the cold temperature front at distance from these wells is unknown. Considering all the above factors and observations, my opinion at this point is that the existing monitoring program, if augmented by a deeper observation well that taps the injection zone at Casa Diablo and if expanded with additional observation wells drilled closer to the thermal springs as needed, will be adequate to detect changes in the hydrothermal system due to geothermal developments at Casa Diablo.

Effectiveness of Proposed Mitigation Measures

Mitigation measures proposed to prevent or reduce impacts of geothermal developments on thermal springs to acceptable levels are contained in the February 11, 1988, Record of Decision for the PLES I Plan of Operation. The thrust of these measures is to require that additional monitor wells be drilled closer to the thermal springs if changes in the hydrothermal system are detected at closer-in monitor wells and that temporary and permanent modifications in the production/injection scheme be carried out to reverse any changes detected at monitor well locations. If such measures are not effective in stopping the migration of induced pressure or temperature changes through the hydrothermal system toward the thermal springs, the final action would be to discontinue power production.

Overall, I think these mitigation measures in combination with the monitoring program provide an adequate level of protection for the thermal springs. Some qualifying remarks are in order, however. First, I recommend that monitor wells at each location be constructed so as to communicate with both production and injection zones, as discussed in the previous section. Ideally, step-out monitor wells (as noted in measures 1 and 4) should be in place before changes are detected in close-in monitor wells in order to determine the natural level of variation in pressure and temperature away from the project area and to assure that induced changes have not already spread away from the project area. Data gathered from drilling step-out wells would also allow a better conceptual model of the hydrothermal system to be delineated for predictive purposes. To lessen the economic burden this would place on the developer, I suggest waiting until power is on line to require that at least one step out well be drilled in the vicinity of Colton Spring. Finally, there appears to be little latitude for changes in production/injection well locations or depths given present lease boundaries and concerns over premature breakthrough of cooler water. This places even more importance on the early detection of induced changes in monitor wells and serious consideration of curtailment of power production if such changes are observed.

Conclusions

The analysis presented in the Papadolpulos report describes one possible way in which the hydrothermal systems could respond to geothermal development. Other types of response are possible. A properly conceived and implemented hydrologic monitoring program should be capable of determining what the actual response is. More importantly, such monitoring provides for early detection of changes in reservoir conditions within project areas and between these areas and the thermal springs. The Papadolpulos report suggests that temperature changes in thermal springs could take place long after the development period is over and hence monitoring cannot provide protection against such impacts. This situation should not occur, however, if reservoir temperature changes in and around project areas are detected by the monitoring program in the early stages of development, and suitable mitigation measures are then implemented.

United States Department of the Interior

GEOLOGICAL SURVEY

January 4, 1988

Comments on impacts of the Mammoth/Chance geothermal development on thermal springs at the Fish Hatchery and Hot Creek gorge

Michael L. Sorey
U.S. Geological Survey
Menlo Park, California

The following comments are intended to more clearly state my opinions and recommendations regarding potential impacts of the proposed Mammoth/Chance development by Bonneville Pacific Corporation on thermal springs at the Fish Hatchery and Hot Creek gorge. My testimony at the appeals hearing on December 14, 1987, may have cast an overly negative light on the geologic and hydrologic uncertainties which exist and the consequent level of risk that this project poses to the thermal springs. I still maintain that the source and extent of hot water to be produced by this project are poorly known at present and that flow tests conducted by Bonneville Pacific in 1985 did not provide sufficient information in this regard. However, I believe it is possible to proceed with this development in a manner that would avoid significant hydrologic impacts, provided several conditions are met.

The first condition is that one or more observation wells be completed in such a way that they are in hydrologic connection with the production reservoir and located between the production area and the thermal springs. Successful completion of such wells may need to await new subsurface information from exploratory drilling and may require several attempts to drill in different locations and to defferent depths. The responsibility for this work should rest with Bonneville Pacific, whereas the responsibility for verifying that the wells are adequate for the intended purpose should rest with Mono County and the Long Valley Hydrologic Advisory Committee. Wells to monitor the impacts of reinjection may also be required if it is determined that changes induced by reinjection could reach the springs before changes induced by production.

With suitable observation wells in place, flow tests on production wells should be carried out to adequately stress the production reservoir, so as to make possible determinations of the source and extent of the available resource and the potential for lateral migration of induced pressure changes toward the thermal springs. Such tests would require that fluid be reinjected as far as possible from production wells. By comparing the results of such tests with additional tests involving reinjection closer in, it should be possible to delineate the degree of pressure support to be provided by reinjection and the likelihood of premature breakthrough of cooler water in production wells.

Recent consultations with Bonneville Pacific representatives has indicated to me their willingness to meet these conditions, as outlined in their draft proposal for short-term resource testing and monitoring. It is my opinion that if observation well drilling and well testing were properly carried out, a satifactory long-term monitoring program were in place, and mitigation measures set forth in the Conditional Use Permit were enforced as needed, the hydrologic impacts of the Mammoth/Chance development would be relatively minor. The same would be true for the Mammoth Pacific developments at Casa Diablo. Furthermore, information and experience that could be gained if these relatively small-scale projects were allowed to proceed would undoubtably assist in determining potential impacts of larger-scale geothermal developments that may occur on adjacent federal lands.

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June 2, 1988

Mr. Michael J. Walker, Manager
Geothermal Operations
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Dear Mike:

In response to your letters of May 25 and 31, GeothermEx has reviewed the May 9, 1988 report of S. S. Papadopulos & Associates titled "Evaluation of Impacts of Geothermal Development within Long Valley". A statement of our qualifications to comment on this report, and our comments, follow:

Qualifications of GeothermEx, Inc.

GeothermEx is a U.S. corporation specializing exclusively in providing consulting, operational and training services in the exploration, development, assessment and valuation of geothermal energy. It is the largest and longest-established such organization in the Western Hemisphere. Its 4 principals have advanced degrees in earth sciences and engineering, and 17 to 30 years of domestic and international work experience in geothermal development. The staff consists of geologists, geochemists, geophysicists, drilling engineers, well-test engineers, reservoir engineers, and economic analysts, most of whom have at least 10 years' experience in geothermal energy, petroleum and groundwater development.

To date, GeothermEx has worked for 165 clients and has performed over 500 projects in 33 countries. Our reservoir engineering services typically include conceptual modeling of the geothermal system based on analysis of exploration data, well log and well test analysis, numerical simulation of reservoir and wellbore, field development optimization, field management planning, and economic analysis. Sixty-five reservoir engineering projects including low-enthalpy, single-phase water, two-phase water, steam and hypersaline reservoirs, have been completed.

Twenty-six of these reservoir engineering projects are located in the United States, including a detailed analysis of the Casa Diablo reservoir. The purpose of that study was to evaluate the resource and its potential for future development. In the study the following data were analyzed:

a) a number of short-term well tests performed during June and July of 1984;

b) daily flow and injection rate measurements for the period January to December, 1985;

c) daily water level measurements for the period August to December, 1985;

d) daily records of produced and injected fluid temperatures for the period August to December, 1985;

e) hourly downhole pressure measurements for the period February 1985 to February 1986; and

f) daily production flowrate measurements for the period June 1985 to February 1986.

This study also included the development of a conceptual hydrogeologic model, both on a local and regional scale, based on detailed drilling records, subsurface temperature and pressure distribution and geochemical data.

Comments on the Papadopulos Report

Although, in theory, the Papadopulos model represents a reasonable approach to making "order of magnitude" estimates of the effect of production on future temperature distribution, the results of the modeling are not valid because of erroneous assumptions made concerning both the available recharge to the Casa Diablo area and the amount of heat in storage. It appears that the modelers did not use the extensive information on these parameters which has resulted from public and private drilling and testing programs undertaken in the area. Clearly, these erroneous assumptions have resulted in erroneous modeling results which grossly overestimte temperature declines in aquifers assumed to be located downgradient from the Casa Diablo development.

Our comments on these topics are summarized below:

1. Available Recharge

The Papadopulos model assumes a recharge rate to the system of 13.0 x 10^{-2} m^3/s of 200°C water. This is equivalent to 2,380 gallons per minute (gpm). Papadopulos states that this value is equal to the total spring discharge. However, the natural lateral flow through the Long Valley geothermal system has been estimated by Sorey *et al.* (1978) to be approximately 5,000 gpm, based on a boron balance of Lake Crowley and assuming that all the boron is contributed by the hot water reservoir. In Farrar *et al.* (1985), the flow from the Hot Creek Springs is estimated to be 4,300 gpm, based on the measured chloride flux entering Hot Creek.

GeothermEx's 1986 analysis of production data from the existing 12.5 MW (gross) plant showed that there was no evidence of pressure drawdown in the reservoir, although the wells produced up to 3,800 gpm. If the overall model of lateral flow is correct, and if the total flow through the Long Valley geothermal system was only 2,380 gpm, drawdown would have occurred in the production wells as a result of production rate exceeding recharge rate. No drawdown was detected. The results of the USGS monitoring program indicate that no decrease in flow rate from the Long Valley hot springs has been detected in the three years since geothermal production began in 1985.

Because there has been no drawdown in the wellfield or at the hot springs, it is concluded that the flow through the system must be greater than 8,000 gpm, based on the measured flow rate from wells and the estimated flow rate from springs. It is probable that the flow is significantly greater than 8,000 gpm because of the following considerations:

a. The lack of drawdown in the production wells, even at the start of plant operations, indicates that the available recharge to the production area is probably significantly greater than the present production flow rate.

b. If the lateral flow model is correct, a map of subsurface temperature distribution indicates that the main discharge of the system is not to the surface in Hot Creek gorge, but to the subsurface in the area beneath Little Hot Creek. This is based on the fact that shallow, subsurface temperatures are hotter in the Union Clay Pit well (236°F) compared to shallow subsurface temperatures near Hot Creek (well Chance 10, 218°F; well

Chance 7, 200°F). This means that most of the natural discharge from the systems is not being measured.

c. The possibility of significant inter-basin flow which was not accounted for by Sorey *et al.* (1978).

2. Heat in Storage

The Papadopulos model for Casa Diablo production simulates two cases reflecting two differing reservoir thicknesses:

a) all four blocks have thicknesses of 1,000 feet,

b) block 1 has a thickness of 1,000 feet, whereas blocks 2, 3 and 4 have thicknesses of only 100 feet.

The sensitivity of the model to block thickness is shown by the results of the two cases on temperature predictions for block 4 (the Fish Hatchery springs block). For case a) temperature in block four dropped only 7° C after 20 years of production plus 130 years of shut-in, whereas a drop of 34°C was obtained for case b) after 20 years of production and 55 years of shut-in.

The thickness of the thermal fluid reservoir providing production to the Casa Diablo wells ranges from about 300 to 400 feet, as defined by temperature profiles. Production is from depths of about 350 to 750 feet; this corresponds to elevations of +6,950 to +6,550 feet msl. Because flow rates from this thickness of reservoir are adequate for power production, deeper production wells have not been drilled. However, an early exploration well (Union Mammoth #1) identified a deeper reservoir beneath the presently producing reservoir. This deeper reservoir extends from an elevation of about +5,300 feet to +4,700 feet, adding another 600 feet to the known reservoir thickness beneath Casa Diablo, and giving a total thickness of about 900 to 1,000 feet. This thickness corresponds to case a) above, in which the temperature drop in block 4 was minor.

Based on what is known of the stratigraphy in the area, there is no reason to believe that this 1,000 ft. thickness decreases to 100 ft. over a distance of 3 miles. Indeed, temperature profiles from well Magma Chance No. 1 indicate a minimum reservoir thickness of 500 feet in block 4. This is a minimum thickness because the well did not reach the bottom of the reservoir.

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3. Effect of Reservoir Cooling on Fish Hatchery Springs

The Fish Hatchery springs originate from a shallow, cool water aquifer contained in young basalt flows ranging in elevation from about +7,050 feet to +7,200 feet msl. A small amount of thermal fluid leaks upward and mixes with the water in the basalt aquifer. GeothermEx's geochemical studies indicate that only about 2% of the flow of the Fish Hatchery springs consists of fluid originating in the thermal reservoir. Consequently, only 2% of the 7°C temperature drop predicted by the model, that is, 0.14°C, would actually affect the Fish Hatchery springs. Even for case b), which is unrealistic, the temperature decline would be only 0.7°C.

Futhermore, the temperature declines forecast by Papadopulos are based on a highly unrealistic decline of 150°C in the production area, whereas it is unlikely that the plant could maintain production, for economic reasons, after a temperature drop of about 30°C, that is, only 20% of the temperature drop modeled by Papadopulos. Based on the Papadopulos model, this means that the reservoir temperature in block 4 would not decline more than about 7°C (20% of 34°C) after 150 years because of economic restrictions on plant operation.

In summary, it is our opinion that the Papadopulos report is based on a number of erroneous assumptions concerning the geology, hydrogeology and heat content of the Casa Diablo system, as well as erroneous assumptions concerning the economic restraints to developing the reservoir. These erroneous assumptions have resulted in a report which is misleading and which can not be used as a guide to predicting future temperature trends related to geothermal development.

Yours truly,

James R. McNitt
Vice President, Exploration

JRM:mjm

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June 15, 1988

Mark S. Ziegenbein
787 N. Main Street
Suite P
Bishop, California 93514

RE: Papadopolous and Associates Report

Dear Mark:

We wish to comment on the report by S.S. Papadopolous and Associates entitled "Evaluation of Impacts of Geothermal Development within Long Valley". The report, in our opinion, is erroneous. The model utilized is far too simplistic and the boundary conditions used do not conform to known and clearly documented facts concerning the hydrologic environment in the Long Valley Caldera. Their failing may stem from their inexperience with geothermal systems which led them to several erroneous assumptions and conclusions to wit:

1. The thermal discharge via springs does not equal the thermal input into a geothermal system as the majority of the heat is convected downwards.

2. The measured thermal discharge used in the calculations is in error by a factor of approximately 2.5 based on references cited in the report but apparently ignored by the authors.

3. No evidence exists to support a thermal reservoir of 200°C in any of the blocks utilized in the study. Evidence from nearby drilling to depths of 5300' indicate significantly lower reservoir temperatures.

4. Using the actual reservoir temperatures and the model temperature declines the proposd Casa Diablo plants would drop below their lower operational limit in 4 years. The plants would have to be retrofitted to handle the lower temperatures. Even so the proposed plants wouldn't last beyond 10 years based on the models calculated temperature drop and equipment limitations. The models prediction of a 15°C temperature decline in a short time would adequately indicate the need for mitigation far in advance of any "irreversible effects".

5. Since the Fish Hatchery springs are a mixture of cold meteoric water and geothermal water, the temperature impact will not be equal to the "reservoir" temperature change but rather proportional to the amount of thermal water in the Fish Hatchery springs. Hence the temperature changes of the springs will be between 0.07°C and 0.67°C depending on which scenario you choose. It is arguable that there is no thermal component to the Fish Hatchery springs, but rather they are warmed as the result of conductive heating during their subsurface movement.

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We suggest that the interaction of warm fluids with their surrounding reservoir rocks leaches the constituents interpreted to represent the mixing of geothermal fluids with the groundwater.

Previous model studies (incorporated in the E.A. for the PLES-1 development) on the impact of development by groups with experience in geothermal clearly show that the temperature effects predicted by Papadopolous & Associates will not occur. In comparison to Pappadopolous & Associates simplistic heat budget model, these previous studies employed more rigorous and comprehensive modeling techniques which match the existing production data from the MBP-1 plant. The Papadopolous & Associates heat budget model will not match the observed production data and in fact is in error with respect to the initial reservoir temperatures by as much as 60°F at Casa Diablo and 110°F at Chance Ranch.

If Papadopolous and Associates wish to invalidate the previous findings, they need to demonstrate why the previously used models are inaccurate by utilizing rigorous calculations that can fit the observed data base.

Yours truly,

Timothy K. Linscott

Timothy K. Linscott
Exploration Manager

TKL/te

JUN 8 1988

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STATE OF CALIFORNIA—THE RESOURCES AGENCY

GEORGE DEUKMEJIAN, *Governor*

DEPARTMENT OF CONSERVATION
DIVISION OF OIL AND GAS
1416 9th STREET, ROOM 1310
SACRAMENTO, CALIFORNIA 95814
(916) 445-9686

June 2, 1988

Sean Hagerty
Department of the Interior
Bureau of Land Management
2800 Cottage Way
Sacramento, California 95825

Dear Mr. Hagerty:

The Division of Oil and Gas is pleased to review the EVALUATION OF IMPACTS OF GEOTHERMAL DEVELOPMENT WITHIN LONG VALLEY, prepared by S.S. Papadopulos & Associates, Inc. for the Bureau of Land Management (BLM). We appreciate BLM's willingness to share this information.

The Division is mandated by the State of California to ensure that wells for the discovery and production of geothermal resources be drilled, operated, maintained, and abandoned in such a manner as to safeguard life, health, property, and natural resources, and to prevent damage to, and waste from, the underground geothermal deposits, and to prevent damage to underground and surface waters suitable for irrigation or domestic purposes.

The Division has also received and reviewed Mesquite Group, Inc.'s draft comments and summary analysis, dated May 26, 1988, on the S.S. Papadopulos and Associates, Inc. Report. For the most part, we agree with Mesquite's findings, and will therefore, not reiterate their comments. Our comments address some areas not covered by Mesquite Group, Inc. and are as follows:

1. Clarification is needed as to the method of designation of area blocks (i.e. block 1, 2, 3, and 4). They acknowledge that the lateral extent of the resources may be controlled by fault zones, which we agree is a distinct possibility. If this is so, the Hilton Creek (Mammoth-Airport) fault zone and the unnamed fault zone to the west trending through the schoolhouse, should mark the boundaries of their chosen blocks. According to the consultants' logic, the hatchery springs, which occur on the unnamed fault zone, would not be effected by production in the Chance Project since most of the Chance wells are on the Hilton Creek Fault Zone, and thus, on a fault block down-gradient from the springs.

2. The report refers to block 4 as the fish hatchery block, yet, the fish hatchery springs are located in block 3.

3. After all the effort the consultants put into their model, why didn't they predict the change in the hatchery springs temperatures as the end product? Since the thermal component of these springs is only 2%-5%, we feel that the changes in spring temperatures would be minor even under the worst predictions for decrease in reservoir temperatures.

4. In equations 3,4, and 6, Tr and Tiw are described as follows: Tr is the temperature of the reservoir, in degrees Celsius; Tiw is the temperature of the inflowing water, in degrees Celsius. How could you multiply the remainder of the terms by temperature in degrees Celsius? Surely the modelers must mean degrees Kelvin. If the modelers actually did use degrees Celsius, the apparent-heat flow into the system would be erroneously low.

5. In equation 6, conductive heat-flow into the system was omitted. The conductive heat-flow as measured at the surface may appear low if the overlying cold groundwater is drawing off the heat. However, the conductive heat-flow into the system may be significant, and would increase in significance if the reservoir temperature actually starts declining as predicted. The increase in thermal gradient would actually cause conductive heat-flow into the system from below and from the sides, to increase, and cause conductive heat-flow out of the system through the top, to decrease.

The Division legislative mandate is to assure that geothermal projects are conducted in an environmentally sound matter. All concerned individuals, local, state, and federal agencies, and geothermal producers are encouraged to work with us in setting up environmentally sound procedures for operating geothermal fields. If we can be of any further assistance, please don't hesitate to call me or Rob Habel at 323-1787.

Sincerely,

Robert S. Habel

for Richard Thomas
Geothermal Officer

cc: M.G. Mefferd
Robert Habel

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